OCTOBER, 1961

Welding Journal

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Welding Journal

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PRESS-TIME NEWS ...about ...People ...Welding ...Products

Ohio State Names Two For NCG Grants

James W. Bradley AWS of Columbus and James H. Frazier of Cincinnati have been selected by Ohio State University as recipients of the National Cylinder Gas Scholarships in Welding Engineering for 1961–62.

Bradley, a senior in the College of Engineering, is vice-president of the society's student branch. His wife is a senior in the university's College of Education.

Bradley was named the first recipient of a National Cylinder Gas award when the scholarship program was started in 1960. This is his second award.

Frazier also is married to a student at Ohio State. Both work part time to assist with their educational expenses. He will be a senior in the College of Engineering.

National Cylinder Gas Division of Chemetron Corp. provides the grants to qualified students selected by the university for use in buying equipment and books and for payment of university fees.

Penn State to Conduct Symposium

The Pennsylvania State University will conduct a Metal Joining Symposium from December 11th to December 13th.

Dr. Karl M. Weigert, assistant professor of industrial engineering at Penn State and chairman of the event, said the presentation will deal primarily with the fields of soldering, brazing and welding procedures and materials. Various filler metals and their physical properties will be reviewed and design features discussed for optimizing joint performance.

Speakers and their topics will include: high temperature fatigue strength, F. M. Miller, Wall Colmonoy Corp.; ductile high-temperature brazing alloys, D. C. Herrschaft, Handy & Harman; ultrasonic welding, J. Raymond Wirt, General Motors Corp.; statistical evaluation of stress analysis data, Harry Schwartzbart, Armour Research Foundation; and optical methods of stress analysis, Dr. George U. Oppel, professor of engineering mechanics, Penn State.

Further information is available from the Conference Center, The Pennsylvania State University, University Park, Pa.

Wells Heads Associated Exhibition

N. Tucker, president, Grosch-Tucker, Inc., has announced the appointment of Chester Wells as President of Associated Exhibition Management, Inc., an associate company of Grosch-Tucker.

Chester Wells

Prior to joining AEMI, Mr. Wells served as manager of expositions for the American Society for Metals with headquarters in Cleveland, Ohio. A well-known figure in the exhibition management field, Mr. Wells has also been secretary and treasurer of the National Association of Exhibit Managers for the past twelve years.

Airco Names Merriman

R. H. Merriman AWS has been appointed manager of the Air Reduction Sales Co. gas marketing department. In his new post, Mr. Merriman will direct the nationwide sale and distribution of Airco industrial gases. Mr. Merriman succeeds Mr. Werly as manager.

R. H. Merriman

Mr. Merriman joined Airco in 1937 as a salesman in the metropolitan New York district. Except for Army service from 1943 through 1946, he continued in this position until 1949, when he was transferred to the Boston district. In 1954, Mr. Merriman became assistant manager of Airco's metropolitan New York district, and in 1958 was made manager of the Buffalo district. Earlier this year, he was manager of the Philadelphia district.

Electrical Manufacturers to Hold 35th Annual Meeting

Electrical manufacturers from all sections of the country will assemble at the Plaza Hotel in New York, N. Y., on November 16th for the 35th Annual Meeting of the National Electrical Manufacturers Association.

The program will be divided into two parts—a morning business session and a dramatic review of the electrical industry's progress immediately after the general membership luncheon.

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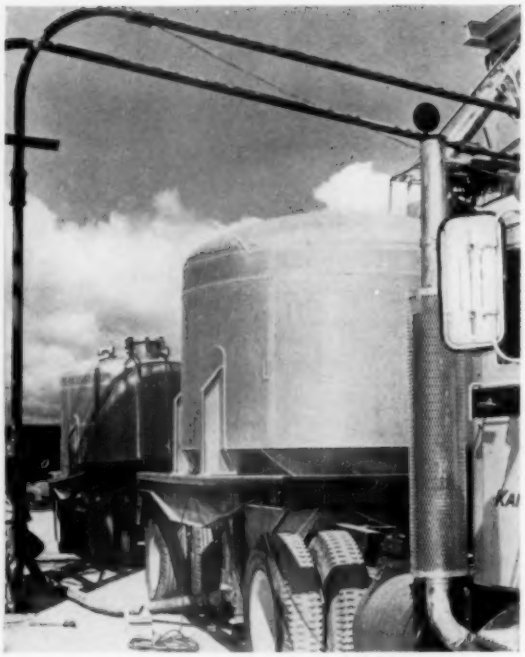
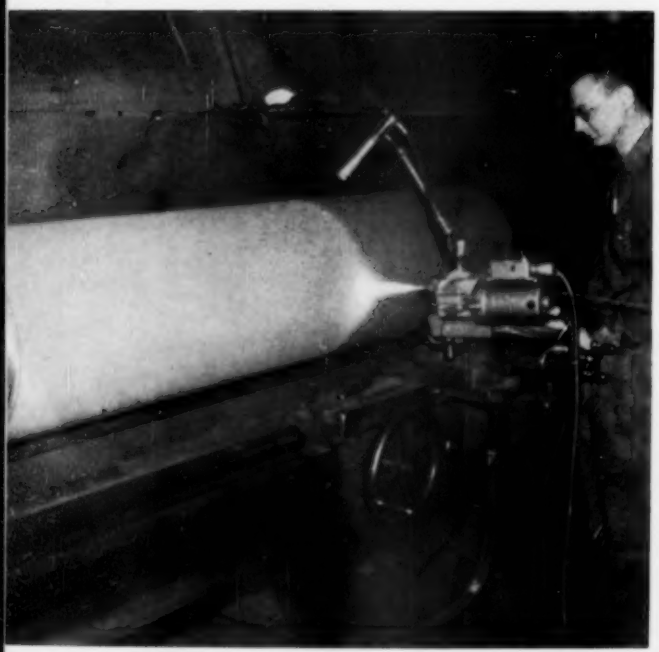
WELDING ZONES

Speedy welding of tanks made of $^{3}/_{16}$-in. aluminum sheet which are used in poultry processing equipment. Westinghouse Electric Corp. supplies a semi-automatic, wire-fed arc-welding gun using a $^{3}/_{64}$-in. AL4043 wire



All-welded pressurized twin tank transport trailer made of aluminum has increased carrying capacity of about 4.5 barrels more than vehicles fabricated of other metals (Courtesy Kaiser Aluminum Co.)



Hard surfacing large aluminum roll used for transporting a thin plastic film using a Metco, Inc. heavy-duty electric drive flame spraying machine

"Treadmill" welding operation geared to automate production of specialized auto frame parts. (Courtesy A. O. Smith Corp.)

"Impossible" welds

Welds that are impossible by any other technique are now routine with Hamilton-Zeiss' high-energy density electron-beam welding. Hamilton-Zeiss equipment offers you unique performance combined with flexibility, reliability and repeatability / Difficult materials, unequal dimensions and deep penetrations present problems that only Hamilton-Zeiss welding equipment can solve with its high-energy density and precision electron-beam focusing by the exclusive Zeiss magnetic lens system. The Hamilton-Zeiss weld, created in a vacuum, offers these significant advantages: virtual elimination of contamination, close control of penetration, low thermal distortion and close dimensional control. Exhaustive tests demonstrate conclusively that welds produced by the Hamilton-Zeiss method are as strong as the original materials. Supporting metallurgical data are available for your inspection / For full information call Hamilton-Electrona, Inc., exclusive marketing agent for Hamilton-Zeiss equipment in the United States and Canada.

1

1 / Penetration study of one-inch thick Type 302 stainless steel reveals an amazing depth-to-width ratio. High-energy density and sharp focusing produce this unique weld with no reduction in the original strength of the material.

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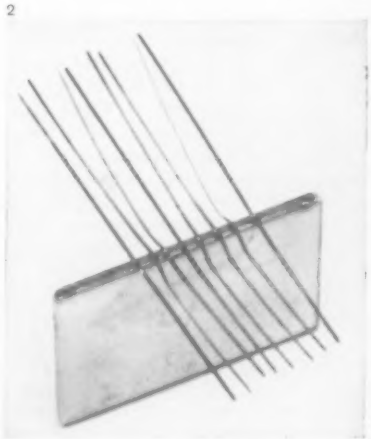
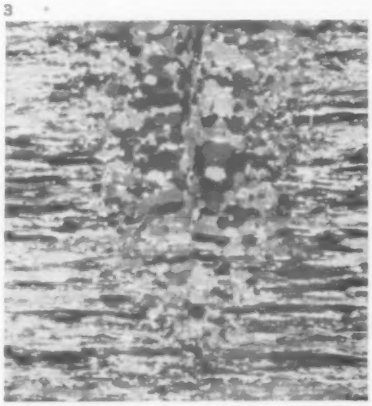


2 / Copper ribbon wires (0.002" x 0.010") welded to the edge of a nickel-plated ceramic substrate. This is just one demonstration of the ability of Hamilton-Zeiss equipment to weld dissimilar materials. Because of the unique design of the Hamilton-Zeiss equipment, electrons travel at approximately 212,000 miles second at the work piece.

3



3 / Study of weld on 0.100" tungsten shows minimum grain growth and no evidence of contamination. The high-energy density beam minimizes grain growth because welding time is extremely short and heat is applied to an exceptionally small zone. Contaminants are eliminated by welding in a high vacuum without filler; impurities are outgassed during the cycle.

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WORLD-WIDE WELDING NEWS

By Gerard E. Claussen

AUSTRIA

The March 1961 issue of *Schweisstechnik* (Vienna) reviews the problem of line voltage fluctuations with accompanying flicker of lighting caused by resistance welders. The advantages and disadvantages of compensation by series and parallel condensers are stated, the decisive factors being economic. In the April issue the Schlatter Synotron slope control system of minimizing line fluctuations is explained.

Frequencies up to 30 cps are provided in a 180 kva machine.

BELGIUM

The January 1961 issue of *Acier-Stahl-Steel* describes the first bridge to be built by automatic welding in Belgium. The bowstring bridge of 296 ft span replaced a Vierendeel bridge destroyed during the war. All shop welding, including girders, flange reinforcement, and stringers, was done by the submerged-arc process. In this issue also are forty photographs of special freight cars, mainly foreign and mainly welded.

Revue de la Soudure for the first quarter of 1961 describes the aluminum alloy reactor vessel for the nuclear power plant at Mol. The vessel contains the Cadmium-Beryllium control rods, is 25 ft long, and is $^{13}/_{16}$ to $2^1/_2$ in. thick. Metal-inert-gas was used.

CZECHOSLOVAKIA

The March and April 1961 issues of *Zvaranie* contains the following principal articles:

- A covered electrode for hard facing deposits metal containing 3.0 – 3.5C, 24 – 27Cr, 1.5 – 2.0B, rem. Fe. The electrode consists of a mild steel core rod with a covering (outzidedrimeter 1.9 x core) containing 8% graphite, 6% ferroboron, 80% ferrochrome, 6% binder. The deposit is 58 – 62 Rockwell C, and the carbide phase was found to consist mainly of Cr_7C_3 and B_4C.
- The Third Five Year Plan calls for the use of eleven standard wires and eight standard fluxes for submerged-arc welding in Czechoslovakia. The three wires for mild steel contain 0.4 – 0.6, 0.8 – 1.1, and 1.8 – 2.2% Mn. The fluxes for mild steel contain about 40% SiO_2, 25 – 40% MnO. For certain alloy steels a bond flux contains 35% Al_2O_3, 50% CaF_2.
- The numerous Czech standards on welding are summarized.
- The curriculum of the welding engineering school at Bratislava consists of 693 hr divided among 21 subjects, including design, welding practice, and metallurgy.
- A combustion method for analysis of welding fluxes for fluorine involves passing oxygen over the sample at 2100° F and absorbing in tenth-normal NaOH solution.
- The notch impact value of weld metal deposited by the CO_2 process was higher with dry CO_2 than with undried CO_2. The water content of commercial CO_2 was not considered harmful, however.
- The electroslag principle was applied to the building up of bosses on plate and to the remelting of scrap from machining operations.
- The sixtieth birthday of Prof. F. Faltus, well-known researcher on welded structures and text books on welding was celebrated Jan. 5, 1961.

EAST GERMANY

Zis Mitteilungen of the Central Institute of Welding for February 1961 is a handbook on training and qualification of welding operators for code or specification work. Gas and arc welding operators must be licensed to work on code jobs. Preliminary instruction consists of a minimum of 352 hr including 8 hr of business science, 292 hr of practical welding and 44 hr of class room work. The latter includes flame cutting, power supplies, volt ampere relations, submerged arc and gas shielded processes, types of joints and electrodes, distortion heat treatment, and codes. The course is completed by an 8-hr examination in which the operator is rated on ten joints he has welded. Rating includes melting dimensional tolerances and passing an oral examination. The successful operator is qualified for the lowest class of work, Class III. For Class I and II work, which includes alloy and clad steels, a more comprehensive course is required.

The March 1961 issue of *Schweisstechnik* (Berlin) deals with repair by welding. Two interesting repairs involved an hydraulic turbine and a pulp digester. The patches welded into the latter were stress relieved by the low temperature process. Equipment for manufacturing and technology of applying powder-core continuous electrodes for building up tools are described. A waterglass-bonded submerged arc flux for building up street-car rails deposits metal containing 0.08 C, 13 Cr, 5 Ni, 3.7 Mn.

Submerged arc welding is used to make the internal and external longitudinal welds in 20-in. pipe for the new line from Russia, through Poland to East Germany. Tandem electrodes each $^3/_{32}$ in. diam are used, the travel speed being 40 ipm.

Zis Mitteilungen for May 1961 contains the following articles aimed at increasing the percentage of automatic welding in East Germany from the present 40% to 70% in 1965.

The Kjellberg line of automatic and semi-automatic machines for submerged arc, metal-inert-gas, and tungsten-inert-gas welding including a tube-to-tube sheet tungsten-inert-gas welder are described with the aid of circuit diagrams. East German generators and rectifiers also are illustrated. A nearly flat characteristic is favored for wire feeders operating on the principle of internal regulation, while a drooping characteristic is best for external regulation. To avoid disturbance to the power network by fluctuating welding load the usual remedies are suggested: compensation by condensers, distributing the load uniformly in each phase, and avoiding synchronization of welding operations.

Compound-wound, cross field, and separately excited generators for manual arc welding were compared for subjective welding characteristics and for oscillographic characteristics on short circuit. Three

DR. GERARD E. CLAUSSEN is associated with Arcrods Corporation, Sparrows Point, Md.

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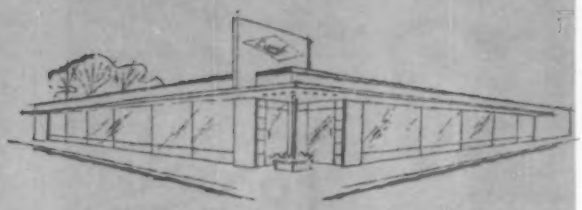

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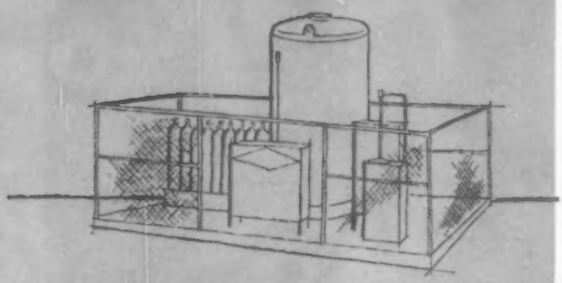

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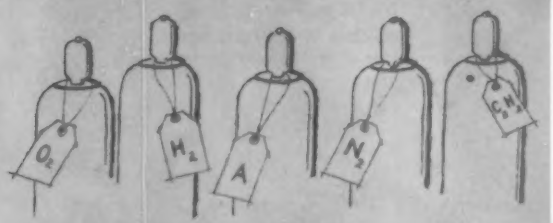

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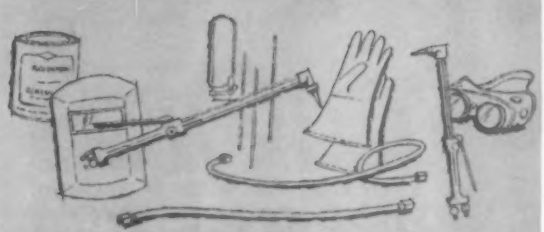

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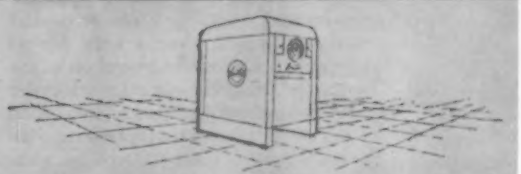
Red Diamond accessories and supplies will make the difference between top-quality welds and Inspector's nightmares. Check your inventory now for welding rods, fluxes, tips, hose, lighters, flints, tip cleaners, etc.



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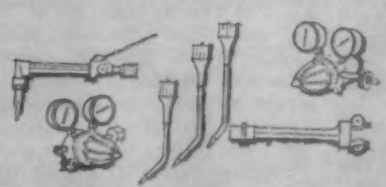

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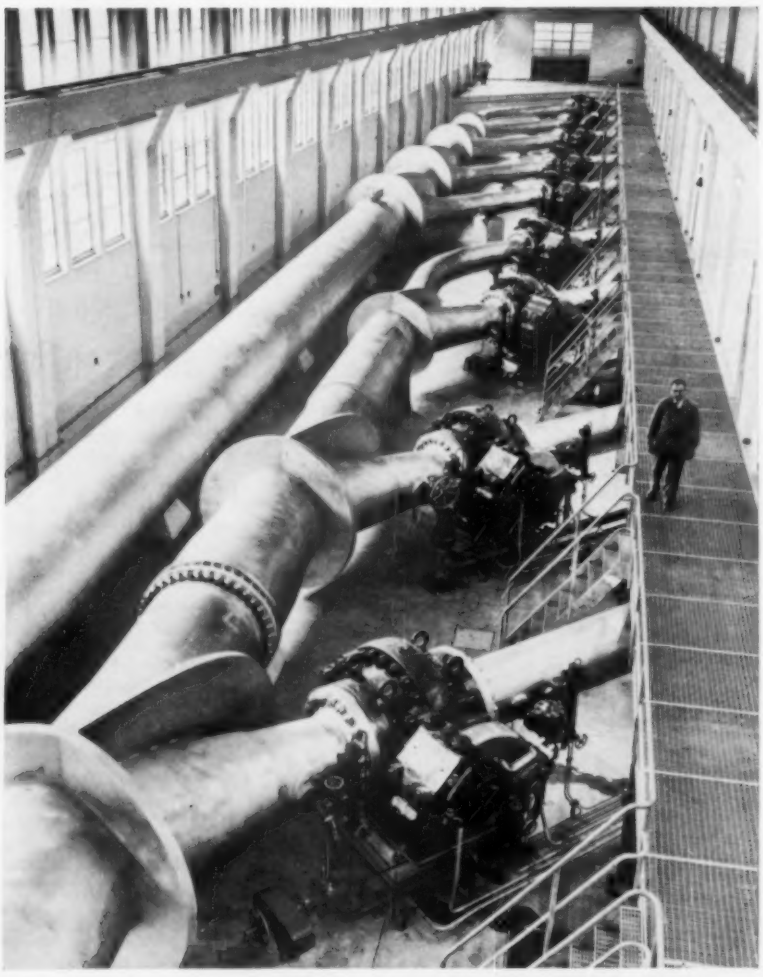
criteria agreed with the subjective evaluation of welding operators: (*a*) Carrer's R coefficient which is the ratio of instantaneous power to average power, (*b*) the ratio of load voltage to the difference between short circuit current and load current, (*c*) the ratio of instantaneous open circuit voltage to short circuit current after it becomes stabilized. The Carrer coefficient was 0.89 to 0.95 for good generators and 0.79 for a poor one. Ratios (*b*) and (*c*) were 0.10 to 0.11 for a poor generator, but were 0.12 to 0.23 for good ones. For CO_2 welding a flat characteristic was judged best.

This issue describes condenser impulse spot welding unit for thin sheet and wire. Impulse time is 0.002 sec.

Schweisstechnik (Berlin) for April 1961 contains the following articles:

- A water-cooled cassette for radiography of welds at temperatures up to 1100° F maintained the film below 104° F by means of circulating water or air.
- Submerged-arc welding of stainless clad steel 1 in. thick resulted in a rather hard stainless steel weld with only 40 to 60° bend angle. The single stainless steel bead used to weld the stainless side penetrated considerably into the mild steel and was up to 485 Vickers hardness.
- To produce uniform penetration in surfacing deposits by submerged-arc welding two parallel electrodes were found to be superior to a single electrode.
- The application of submerged-arc welding to the fabrication of machine bases with weight savings is explained. The design principles for welded press frames also are explained.
- A resistance butt welding unit for joining carbon steel wire in the wire mill is illustrated. The transformer has 15 steps from 0.8 to 2.5 kva and electronic time control permits welds from 3 to 50 cycles in 23 steps.
- Transducers are applied to the regulation of the speed of wire feed motors in automatic welding heads.

SWITZERLAND



Distribution pipes at Mauvoisin hydroelectric power station fabricated by welding. (Courtesy Oerlikon Machine Tool Works, Buehrle & Co.)

FRANCE

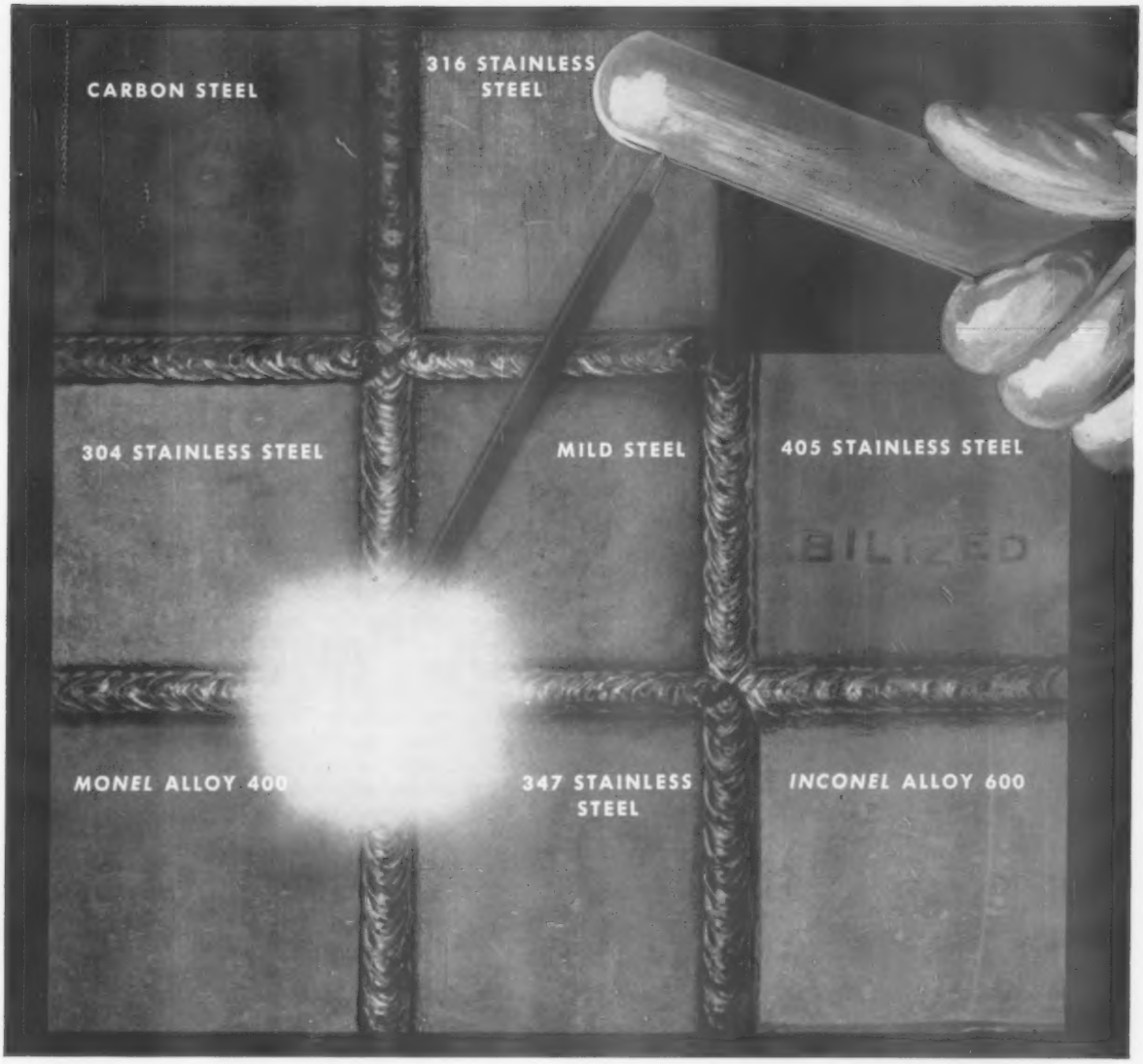
The March-April 1961 issue of *Soudage et Techniques Connexes* deals with specifications and codes for welded construction. The first article summarizes design formulas in French and foreign codes. The design situations range in complexity from butt welds in static uniaxial tension to beam-column connections in torsion, and include fatigue. The stress ellipse for transverse fillet welds is $S^2 + LT^2 = a^2No^2$ where S is the normal stress on the throat section; T is the shear stress on that section; L is 1.8 to 2; a is a coefficient depending on quality and thickness, and No is the comparison stress equal at least to the maximum permissible stress in uniaxial tension on base metal. Eight French codes are discussed:

Code CM56 for building
Bridge Code
MTPS Code on lifting devices
Unfired pressure vessel code, including the International Boiler Code /SO/TC11.
Code for petroleum storage tanks
Code for gas pipe lines
Code for petroleum pipe lines

Five articles discuss the proposed French classification of welds for plate fabrication, including sheet metal. The logic in favor of standardization of welds is admitted, since components to be welded, such as pipes and flanges, are standardized. Measurements of fit up, reinforcement, root gap, convent and undercut made over a long period of time in a pressure vessel shop are summarized. Specimen work order and inspection sheets are explained for a shop fabricating pressure vessels for low temperature service. Tolerances in penstock work are reviewed.

The French Institute of Welding showed that ultrasonic inspection cannot yet replace radiography for spot welds. Research on improving the ultrasonic inspection method is under way.

Tests in four countries show that welding cables 0.025, 0.078 and 0.155 in. cross section of copper can withstand 150, 360 and 550 amp, respectively at 60% duty, 95° F ambient and 140° F maximum.



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RWMA's Interest in Research

RWMA (Resistance Welder Manufacturers' Association) has actively supported research in resistance welding since its formation in 1936. It has contributed both financially and with individual's time to the Welding Research Council. In past years it has sponsored programs at R.P.I., University of California, etc. Its latest project is a seam welding program, performed on equipment contributed for this purpose, at the University of Texas.

As a direct stimulus to research RWMA has, in past years, often offered a prize paper contest for studies on resistance welding encouraging engineers to publish their accomplishments so the welding community at large may derive benefit from their work. To provide a continual flow of new material, a program has been established whereby three member companies present papers at the annual national AWS Spring meeting.

RWMA has promoted activities to distribute welding data. Some of these activities are: the RWMA Manual originally published in 1942, recently revised and issued in 2 volumes; issuance of RWMA bulletins on welding, the production of an I.C.S. course on resistance welding; the loan of films and the supplying of speakers for local and national AWS and other groups.

RWMA continually cooperates with other groups such as A.S.A., A.I.E.E., A.W.S., N.E.M.A., and the Military Aeronautical Standards, in the transmission of information and the formulation of standards.

Laboratories of the member companies develop unique techniques which are supplemented by the ingenuity of the design engineers to result in new types of equipment. Examples are welding machines for transistors, for strip in steel mills, for making road mat, for vinyl coated steel, for joining copper to aluminum, in automated lines wherein they are integrated with forming and materials handling equipment.

Considering the size and sales volume of the RWMA members and the absence of government sponsorship of research projects, its members expend a prodigious amount of energy and dollars to keep their products in step with the requirements of modern manufacturing methods.

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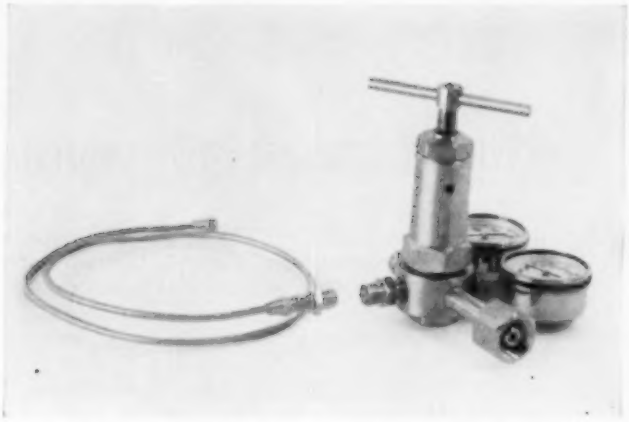

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Welding spacer to structural wall

Insulation Attachment by Welding for An Aircraft **Nuclear Propulsion** Power Plant

involves special techniques and is best carried out with the gas tungsten-arc spot-welding process

BY T. D. McLAY AND R. J. CAMPBELL

Introduction

An aircraft power plant with unlimited range capabilities has many attractive defense and offense advantages. The Aircraft Nuclear Propulsion Dept. of the General Electric Co. thus undertook research and development to produce such a power plant. An aircraft powered by a direct air cycle nuclear turbojet can provide unlimited range by utilizing a nuclear reactor in place of the chemical combustor. Controlled nuclear fission can provide large amounts of energy to power this turbojet. This is possible when one considers that 1 lb of Uranium-235 produces as much heat as the combustion of 1,700,000 lb of aircraft fuel.

In a direct air cycle nuclear power plant, air is drawn in through the intake into a compressor (Fig. 1.) The compressed air is then heated in the nuclear reactor, expanded in the turbine section

T. D. McLAY is in design engineering and R. J. CAMPBELL is in development manufacturing with the Aircraft Nuclear Propulsion Dept., General Electric Co., Cincinnati, Ohio.

Paper presented at the AWS 42nd Annual Meeting held in New York, N. Y., Apr. 17–21, 1961.

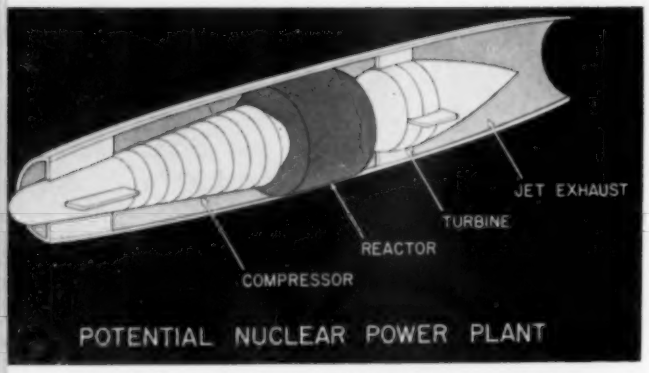


Fig. 1—Direct air-cycle nuclear turbojet power plant

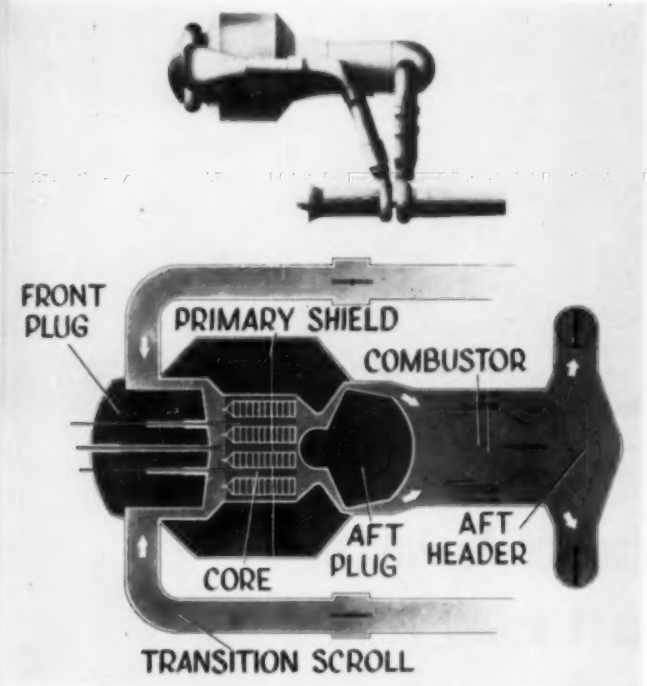


Fig. 2—Cross section of heat transfer nuclear reactor No. 3

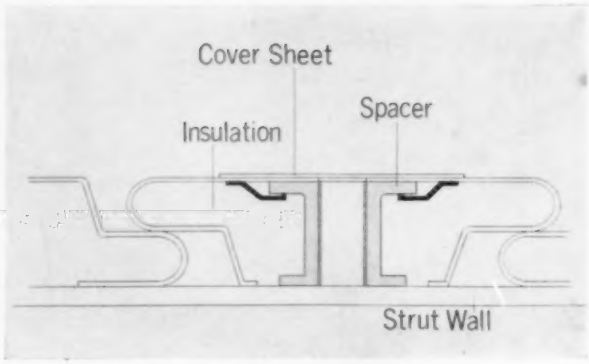


Fig. 3—Schematic depicting interlocking edges of two insulation pads to permit differential expansion at operating temperatures

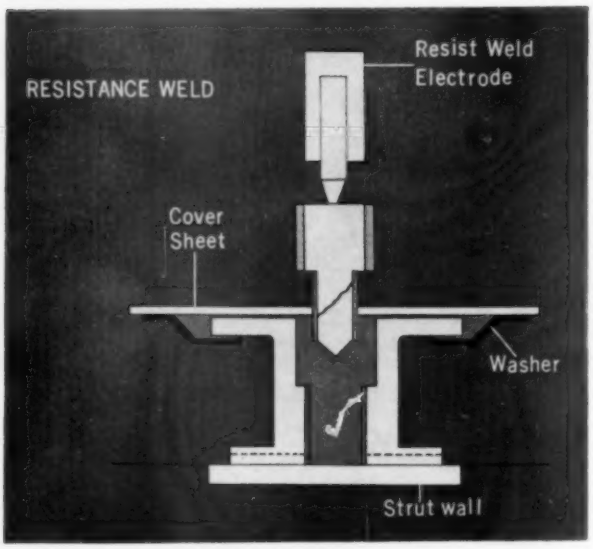


Fig. 4—Insulation spacer attachment by resistance stud welding

and exhausted through the jet nozzle. The jet of hot gases leaving the exhaust nozzle provides the thrust to propel the aircraft.

The problems associated with providing a reliable nuclear turbojet engine involve many engineering disciplines. The design of reactors, shielding and control systems involve detail design of critical long life components. All of the requirements imposed on conventional chemical fuel aircraft engines, as far as weight is concerned, must also be adhered to in nuclear turbojet engine design. The sections of the engine downstream of the reactor must operate for long periods of time at high temperature and must withstand nuclear radiation. The components of the power plant must also be capable of being fabricated using both mechanical and welding techniques to produce parts that have a service life measured in thousands of hours.

In order to evaluate component designs for the nuclear engine, heat transfer reactor experiments were performed. In these experiments, reactors, controls, ducting systems, shield components and auxiliaries, assembled into a power plant, were given performance and life tests to determine the suitability for future consideration in flight versions of the nuclear engine. One of the tests, designated Heat Transfer Reactor Experiment No. 3 (HTRE No. 3), is shown schematically in Fig. 2. It can be seen that this power plant has two levels. The top level contains the reactor, shielding and starting combustor; the second level contains the modified turbojet engine. All of the parts subjected to the hot exhaust gases had to be protected from this environment by insulation. This protection permitted the load carrying structural wall to operate

at a lower temperature than air stream temperature. In Fig. 2 the parts requiring protection were all the structural members downstream of the core. Protection is provided by placing fibrous thermal insulation on the inside surface of the aft plug shield, combustor, header and ducting (Fig. 2). Since it is impossible to hold fibrous thermal insulation in a high velocity air stream without protection, individual sheet metal pad assemblies (to contain the insulation) were designed. Attaching the sheet metal insulation pads required a rigorous design analysis and a significant breakthrough in joining technique.

Engineering Design Requirements of the Insulation Pads

The design requirements of the insulation pad were as follows:

Design life,	1000 hr
Air temperature maximum,	1600° F
Air pressure,	45 psia
Structural wall temperature,	120 lb/sec max
Weight flow lb/sec	120 lb/sec max
Insulation drag load,	10.2 lb/ft of pad width
Maximum pressure difference across the pad	3.5 psi

Discrete insulation pads were used to permit differential expansion between the hot cover sheet and the cooler structural wall. Each pad was framed with a channel to interlock the edges of the pad in the direction of air flow (Fig. 3). The pads were secured to the structural wall at regular intervals using specially designed fasteners. The design loads dictated a nominal fastener spacing of 4 to 5 in. on each pad. Because of the difference in temperature between the hot cover sheet and the structural wall, a sliding connection between the insulation fastener (attached to the structural wall) and the hot cover sheet was required. This was provided by a depressed washer spot welded to the hot cover sheet. The washer contained the spacer and allowed for the required thermal movement. A detail of the fastening arrangement is shown in Fig. 3.

The material used in the insulation pad, fastener and washer was AISI 310 stainless steel. This material was selected because of its stress rupture properties at the maximum operating level at 1600° F. Weldability and formability properties of this material made it an attractive high temperature alloy to fabricate into the required complex shapes in the rear shield, combustor and cut system.

The assembly procedure used to put the pad together was as follows:

1. Sheet metal was shaped to the contour of the structural components.
2. The channels, framing the cover sheets, were formed and spot welded to the insulation pad edges.
3. Holes for positioning the fasteners were punched. The washer and fasteners were positioned using the holes as a template.
4. The fasteners were placed inside the washers and the washers were spot welded to the cover sheet.
5. Insulation was placed in the pad and was held by the spacer and channels.
6. The completed pad was positioned on the component and the fasteners were welded to the structure.

Fastener Attachment Problem

The most difficult part of this design was devising a positive means of holding the fastener to the structural wall. The fastener was required to withstand the drag load tending to push the pad downstream, plus the differential pressure across the pad. The design limitations on the fastening technique were as follows:

1. It had to be small in size.
2. The fastener must be connected from one side only. (Holes in the structural wall would have allowed the escape of hot gases.)
3. The process for attaching had to be portable, semiautomatic and small enough to fit inside of a 24-in. diam duct.
4. The method used could not be serviced during the operating life of the component.
5. The connection between the structural wall and each fastener had to be maintained under the design loads outlined above.

With the above criteria, the only possible answer conceived, at the start of this program, was a stud welded to the structure as shown in Fig. 4. It was decided that, to withstand the loads outlined above, the stud would have to be made from AISI 310 stainless steel, 0.188 in. in diam.

Welding Process Evaluation

Resistance Stud Welding

The initial choice for stud welding consisted of modifying a portable resistance welding gun to accept the stud; the upper portion of the stud was recessed into a bored hole in the copper electrode. The stud, as shown in Fig. 4, was tipped to make the high resistance contact at the structural wall. The lower portion of the stud was ceramic-coated (as well as the inside diameter of the fastener) to provide an electrical resistance to arcing. At the point where the stud protruded above the top surface of the insulation fastener, it was necked down. After welding, the upper portion of the stud was twisted off. Then the top of the stud was welded to the top of the spacer. The bottom flange of the insulation fastener (in contact with the structure) had four grooves to allow for escape of hot gases during the weld.

It was determined that the minimum tensile strength at room temperature of the weld would have to be 80% of the base material in order to with-

stand the loads on the fastener at elevated temperatures.

Investigation of this method of welding showed that the best weld efficiency was only 50% when considering all of the variables, and optimizing them. Furthermore, when welding currents and spring force on the portable resistance welding gun were increased to try to obtain better weld efficiencies, a column shearing failure occurred in the stud.

At this point, it was obvious that another method of welding the stud had to be devised. A straight forward arc stud welding was then tried.

Arc Stud Welding

The insulation fastener was modified (at the base) by machining eight air grooves, and the stud was again ceramic-coated. The cavity at the base of the fastener was increased to allow for build up of metal from the stud weld. Results were encouraging. A cross section of the spacer and stud assembly is shown in Fig. 5. Although cross sections of the weld showed that unsymmetrical welds occurred, weld efficiencies in the neighborhood of 80% could be achieved. Under closely controlled welding conditions, it was proved that a consistent weld could be made.

Engineering requirements specified a quality control procedure of the weld, using the resistance welding specification MIL-W-6858 as a guide. Qualification of the final welding schedule required 25 welds to be tensile tested. The weld joint efficiency of the welds, as a result of tensile testing, had to be a minimum of 80%. During assembly of the insulation pads, after every 12 fastener welds were made, three welds were tensile tested. These test welds had to meet minimum requirements.

Using this joining process and method of quality control, the insulation pads were installed in the HTRE No. 3 power plant. (Figure 6 depicts the insulated island of the aft plug.) However, considerable time was consumed in maintaining the qualified welding schedule, due to the following:

1. The ceramic coating was not always evenly coated on the stud.
2. A loose pin in the stud gun chuck would not pass sufficient current to complete a sound weld.
3. The geometry of the cavity and tolerance stack-up at the base of the fastener were troublesome.

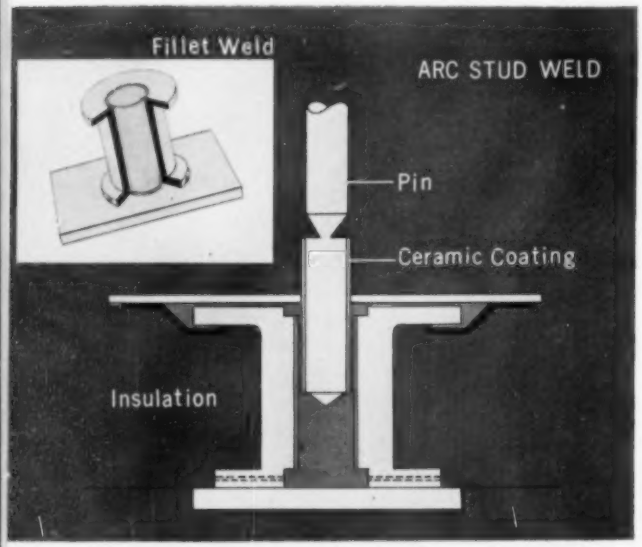
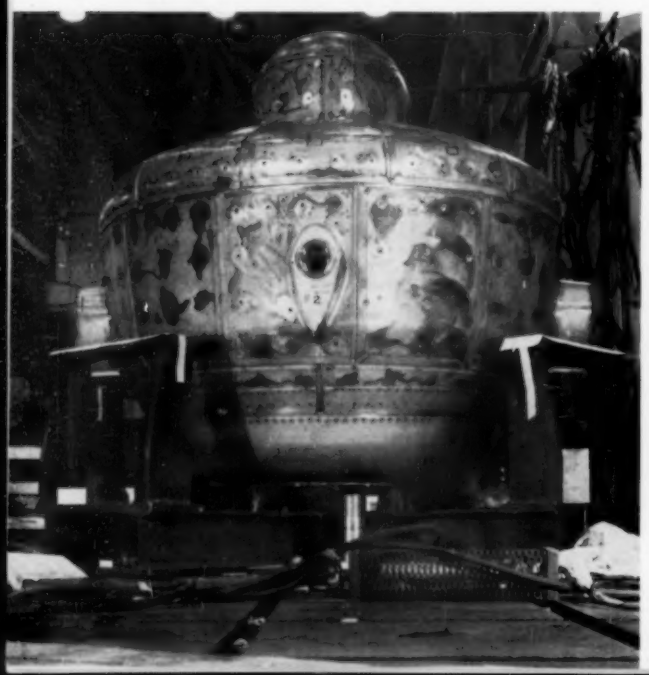


Fig. 5—Insulation spacer attachment by arc stud welding

Fig. 6—Insulated island of the aft plug on heat transfer nuclear reactor No. 3 after arc stud welding



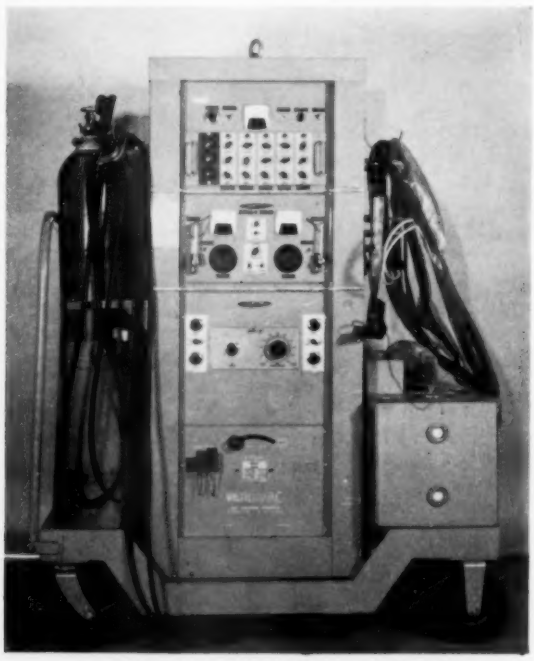


Fig. 7—Gas tungsten-arc spot-welding equipment

4. Improper spring tension on the stud welding gun could cause faulty welds.
5. The angle of the gun relation to the side walls (combined with voids in the coating) was a critical factor.
5. Primary voltage fluctuation of the power supply was a variable which caused a high scrap rate.

As a result of the above factors, joint efficiency was relaxed to 60% in components that were not highly stressed.

After completion of the insulation of the hot portions of the HTRE No. 3 power plant, it was felt that an improvement of the design should be made. Elimination of the stud was a step that would simplify the design. Removing the stud would also help to reduce the hot spot in the area of structural wall next to the insulation fastener. Eliminating the stud would also help to decrease manufacturing costs of the stud and the labor required to join the top of the stud to the spacer.

The solution first suggested involved the use of gas tungsten-arc welding for plug welding the base of the fastener to the structural wall. This process answered the requirement of eliminating the stud and providing a sound weld. Although it did not appear to be a feasible solution for welding a duct of any size under less than ideal laboratory conditions, the process did appear to warrant further study.

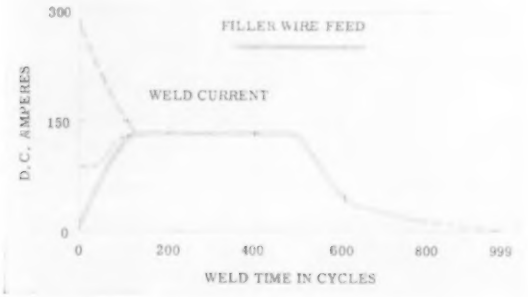


Fig. 8—Typical welding schedule

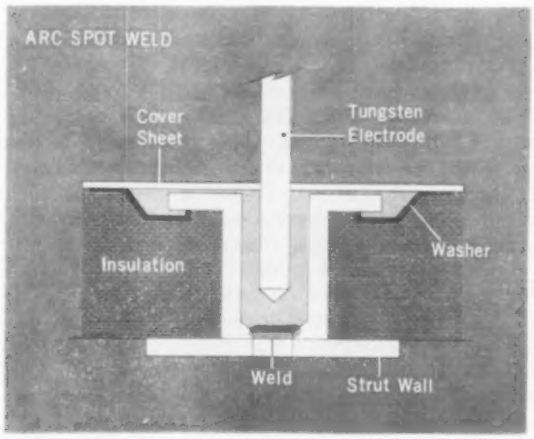


Fig. 9—Insulation spacer attachment by gas tungsten-arc spot welding

Gas Tungsten-Arc Spot Welding

The Process

The gas tungsten-arc spot-welding process is used in light gage metal fabrications involving lap joints of the type employed in resistance welding. Joints of the highest quality and consistency are achieved using this joining process, and the ability to make weld joints from one side only gives wide scope to the design engineer. Although its use has been limited to joining flat surfaces, its adaptation to the deep hole plug welding operation (required on the insulation spacer) appeared feasible.

This phase of the program was conducted to determine the problems and critical parameters associated with the tungsten-arc spot-welding process for joining the Type 310 stainless steel insulation spacer to the Type 304 stainless steel structural wall.

Welding Equipment

The gas tungsten-arc spot-welding d-c rectifier power supply and the welding gun used in this phase of the investigation are depicted in Fig. 7. Silicon diode rectification is employed for the power supply because of the low forward resistance and high response. Ten-turn potentiometer presetting of arc current slopes and various heat levels (Fig. 8) is an integral part of the high performance amplifier used to drive the magnetic amplifier. The magnetic amplifier, in turn, is controlled by an inductive feed-back signal. Electronic pulse counting tubes are used for programming the parameters of the weld cycle. Preflow and post-flow timers are included for controlling inert gas flow to the weld area. Quick transfer to another type of shielding gas is available by the use of the two flowmeters on the front panel of the machine.

Inherent Variables Affecting Welding

Engineering design requirements had defined the over-all shape of the insulation spacer shown in Fig. 9. As previously mentioned, stress calculations indicated that the service condition, to which the spacer would be subjected, required a weld deposit free of cracks or porosity and had to meet a minimum tensile load of 2400 lb at room temperature.

Determining the feasibility of using the tungsten-arc spot-welding process for meeting these requirements was begun by listing the variables that were most likely expected to effect the weld quality and weld nugget configuration as shown in Fig. 9. These variables are listed as follows:

1. Method of tungsten electrode alignment.
2. Composition, size and configuration of tungsten electrode.
3. Arc length.
4. Type of shielding atmosphere.
5. Weld joint design.
6. Welding arc current and time.

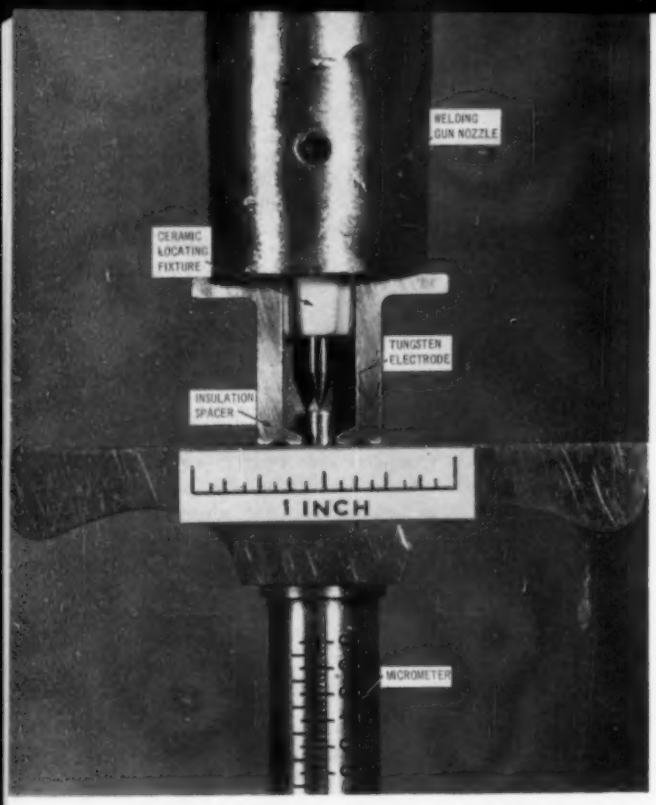


Fig. 10—Photograph showing the ceramic fixture for accurately locating the tungsten electrode within the insulation spacer

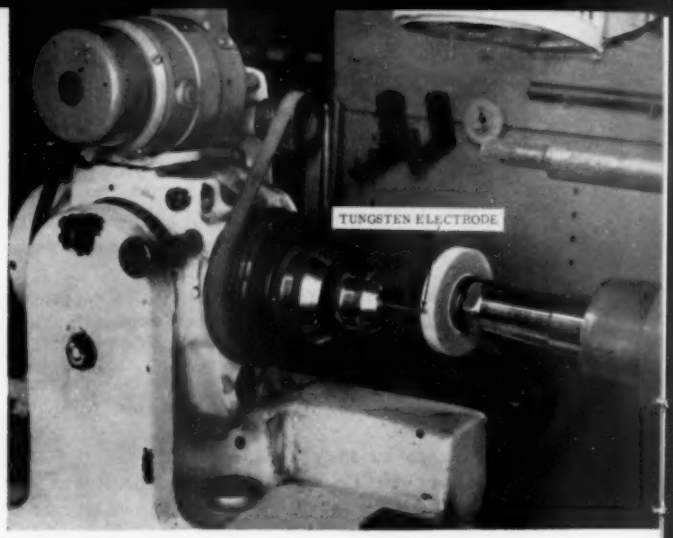


Fig. 11—Pointing tungsten electrodes using precision grinding equipment

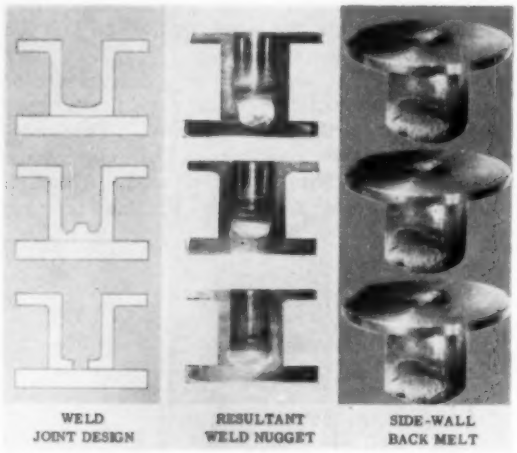


Fig. 12—Joint design evaluations

The combination of these six variables imposed conditions for which there was no common method of attack. A study of these variables revealed that each was interdependent upon one or more of the other.

Electrode Alignment

In order to obtain the symmetrical weld nugget contour shown in Fig. 9, it was quite obvious that a fixture had to be designed for mechanically aligning the longitudinal axis of the tungsten electrode on the same centerline as that of the internal diameter of the spacer. The fixture had to be made from a high dielectric material in order to electrically insulate the tungsten from the metallic insulation spacer. This same material had to have the additional requirement of being resistant to the high temperatures of the welding arc.

Vitreous alumina was selected for the fixture material because it fulfilled all of the above mentioned prerequisites. The design, shape and size of the locating fixture and its incorporation into the welding gun nozzle is shown in Fig. 10. The grooves on the outside-diameter of the locator provided a means of getting the shielding gas into the welding zone and the micrometer was employed for accurately measuring the arc length.

Electrode Composition, Size and Configuration

The satisfactory behavior of gas tungsten-arc welding arcs is controlled by electrode composition and configuration. In tungsten-arc spot welding, ease of arc starting and arc stability are important. Arc starting is readily accomplished when electrodes with a thorium addition are used. Further improvement in starting is obtained when the cathode configuration is such that a sharp electro-static voltage gradient is established at the tip of the electrode. This gradient can be obtained by pointing the electrode, since it confines the resistance heating to the tip of the electrode and sharply limits the possibility of arc oscillation associated with blunt tungsten electrodes.

The ohmic resistance of a 0.010-in. diam tungsten electrode is many times greater than the resistance of a 0.125-in. diam electrode. When the same welding current is passed through each electrode, the smaller diameter electrode is resistance-heated to emission temperatures for a considerable part of its length, whereas heating of the larger electrode is confined to its tip. With fine diameter electrodes, the arc is found to climb up the electrode intermittently due to availability of spots which momentarily have lower emission energy requirements.

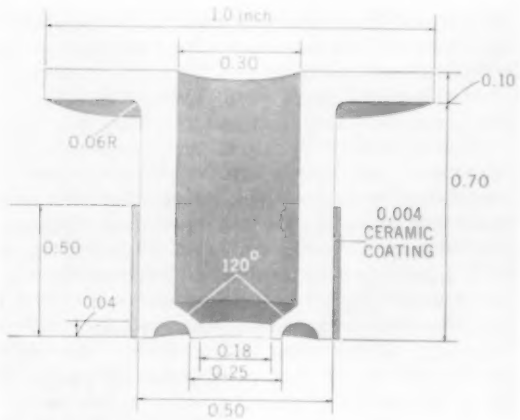


Fig. 13—Dimension of final weld joint design

While arc starting is not greatly affected as long as a sharp tip is maintained, arc stability is not assured when fine diameter electrodes are used.

A 0.125-in. diam tungsten electrode containing a nominal 2% thorium was used throughout this investigation. The degree of taper produced on an electrode will govern, to some extent, the amount of erosion that will take place. Three different electrode preparations were evaluated in a series of tests designed to indicate the most suitable shape:

1. Tapered to a point over a length equal to *two* diameters.
2. Tapered to a point over a length equal to *three* diameters.
3. Tapered to a point over a length equal to *five* diameters.

Accurate symmetry and point angles were obtained using precision grinding equipment shown in Fig. 11. A maximum current of 210 amp was used with an arc length of 0.060 in. Results indicated that there was less erosion on the two diameter tapered electrode, and it was therefore adapted as the final tip geometry.

Preliminary Experiments

An experimental welding development program was conducted to define the relationship between time, current, shielding gas and weld joint design. These four variables had direct control over the nugget contour, strength and cracking of the plug weld. Engineering design had frozen the over-all shape of the spacer, and the only area which lacked definition was the weld joint at the base. As previously mentioned, the strength of the final weld had to have a cross-sectional area which would meet the 2400 lb tension testing load specified.

The first joint preparation tried was a lap joint similar to the type normally requiring the use of this particular joining process. It was prepared simply by machining a flat base in the bottom of the spacer and is shown in Fig. 12. Using this weld joint design, a series of various arc lengths, weld times and arc currents, were investigated using shielding atmospheres of argon, helium, 75% argon – 25% helium, and 85% argon – 15% hydrogen. The weld nugget cross sections produced were generally lopsided, and approximately 50% had "burn-through" as shown in Fig. 12.

Although the vitreous alumina locator and the internal diameter of the spacer had been machined to very close tolerances ±0.003 in., it was the opinion of the authors that the stack-up tolerance on these two dimensions accounted for some misalignment of the tungsten electrode, thereby resulting in the lopsided nugget. Since the development had to be geared to production conditions, further refinement of machining tolerances appeared impractical. Weld nugget concentricity was then attempted by the use of the hat joint depicted in Fig. 12. Again, lopsided welds resulted, and approximately 50% of the side wall burned-through. Assembly difficulties were foreseen with both of these joint designs, since it would be very difficult to inspect the fit-up condition between the spacer and the structural wall prior to welding. It was also felt that, if the arc could be initiated between the tungsten tip and the structural wall, it might aid in producing a concentric weld nugget. This led to the modification in the design of the bottom hole joint as depicted in Fig. 12. The resultant weld nugget configuration was improved. However, burn-through on the side wall was still a problem.

Controlled heat flow is an inherent part of any successful thin metal welding operation. The magnitude of the arc current, arc length, weld time and shielding gas determine the instantaneous temperature of any weld pool. When the combination of the above factors is such that a higher than optimum metal temperature is reached in the pool, the surface forces which hold the molten metal are reduced. In this case, the mass of the spacer side wall was less than the mass of the structural wall. The arc energy therefore, had to be dissipated at a rate which would prevent the mean temperature of the side wall from exceeding a value that caused the burn-through condition. To accomplish this, a heat choke in the form of a radius was machined in the base of the spacer. In addition, a 0.004-in. ceramic coating was applied to the outside diameter of the spacer to protect it from excessive oxidation during welding; it aided in completely eliminating the burn-through condition. Other types of protective shieldings such as an inert atmosphere were sidelined because of the expense and mechanical difficulty in insuring protection during manufacturing operations.

A cross section of the finalized weld joint design before welding with the protective ceramic coating is depicted in Fig. 13. Initial welds made with this geometry resulted in concentric weld nuggets. However, the resultant nugget cross-sectional shear area was below that required to obtain the 2400 lb tension load. To obtain the required shear area, the root face was increased to 0.080

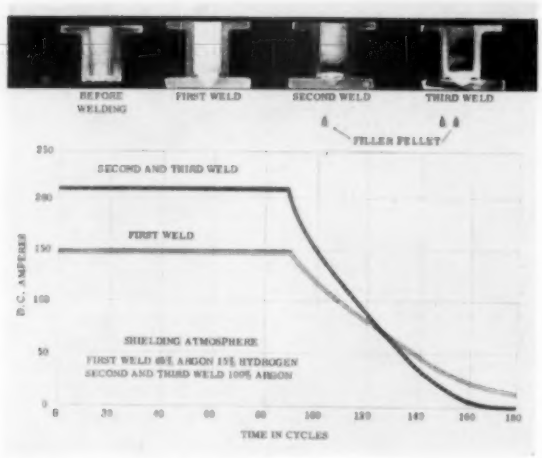


Fig. 14—Final welding schedule

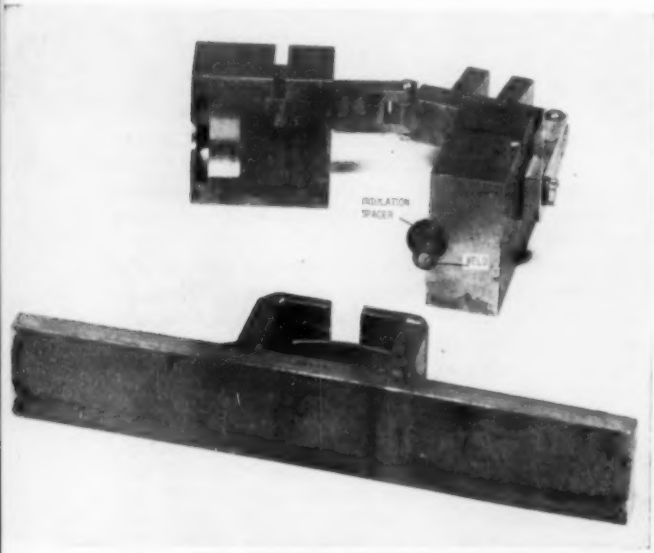


Fig. 15—Tensile testing fixture used for weld evaluation

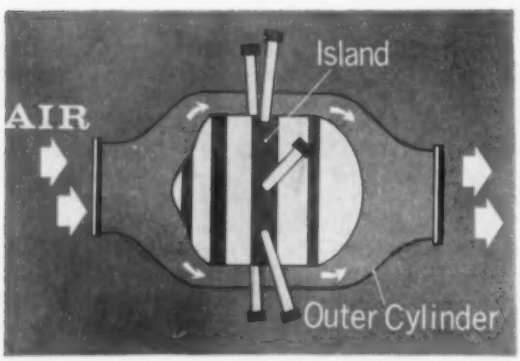


Fig. 16—Schematic of a test component for evaluating insulation design and method of attachment

in. It was then observed that the increased root face resulted in a decrease in weld penetration and a lopsided weld nugget.

At this point it was quite obvious that the problem would have to be rectified by adding filler metal to the weld joint by some other means than incorporation into the joint design. This was accomplished by first welding the spacer to the structural wall using the 0.040-in. root face design. A shielding mixture atmosphere of 85% hydrogen – 15% argon was used for this first weld, resulting in a larger nugget because of the greater amount of heat generated per ampere compared to other types of shielding atmospheres. Filler metal was added during the second and third welds, using a 0.188 in. diam Type 310 stainless steel pin which was 0.125 in. long and machined at one end to a 120 deg. included angle for initial arc stabilization. The shielding atmosphere for the second and third welds was 100% argon, because previous development work had shown that the 85% argon – 15% hydrogen mixture resulted in weld metal porosity on multiple pass welding. A complete graphic picture of the finalized welding schedule is shown in Fig. 14.

The tensile testing fixture employed to evaluate the strength of the weld is shown in Fig. 15. The average strength of these welds under tensile loading was 2800 lb. This was 20% greater than the specified minimum load of 2400 lb.

Manufacture of Test Vehicle

Prior to the fabrication of most large and expensive

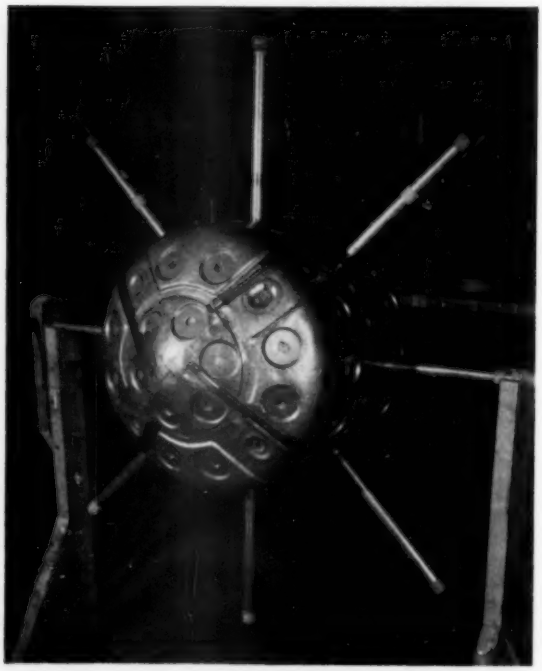


Fig. 17—Island structure of the test tank

components, it is often necessary to make mock-up assemblies to evaluate engineering designs and manufacturing procedures. Figure 16 shows a schematic view of a test component called the compound-complex or the C-C tank. This structure is representative of a portion of the air stream geometry of a particular portion of the power plant. As previously stated, this area is exposed to the hot gases of the reactor, and it is necessary to provide a thermal barrier so the structural materials can effectively be used to carry the mechanical and pressure loads of the system. In order to evaluate the insulation design and the plug weld attachment for high temperature service conditions, a C-C tank test vehicle was manufactured.

The island structure of this tank is depicted in Fig. 17. The tank was fabricated from 0.125-in. thick Type 304 stainless steel, and the pipes extending out of the tank were used as supporting struts to position the island inside of the outer tank. The pipes also permitted an exit for the thermocouple wires used to measure the temperature of the hot cover sheet under thermal loading. Figure 18 is a close-up view of an area around one of the strut arms. The outer sheath was made from 0.010 in. Type 310 stainless steel foil, and it captured the fibrous insulation over the Type 304 stainless steel structural walls. The small diameter hole cut-outs aided in positioning the insulating spacer for welding.

The under side of several hot cover sheets just prior to plug welding are shown in Fig. 19. During the experimental phase of the tungsten-arc spot-welding program, one area was overlooked which nearly caused serious difficulties in welding the spacer to the C-C tank structural wall. All of the experimental work had been done on samples in which there was surface to surface contact between the base sheet and the spacer. During manufacture, however, stack-up tolerances on the hot cover sheets caused an air gap between the bottom of the spacer and the structural wall. It was quite obvious that, if an air gap did exist, a weld deposit could not be made using the established procedures that would meet the engineering design load requirements. The problem

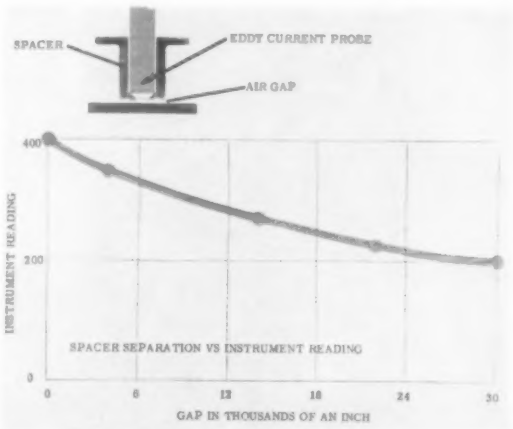


Fig. 20—Calibration curve of eddy current needle deflection vs. air gap

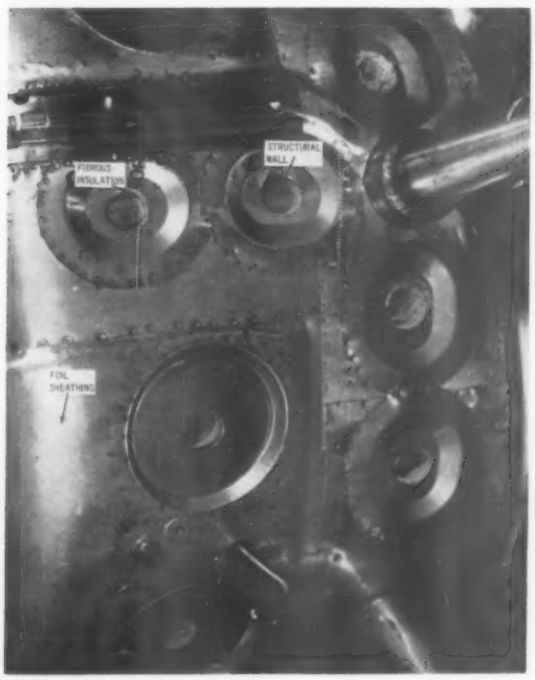


Fig. 18—Close-up view of the island depicting the structural wall, insulation and foil sheathing

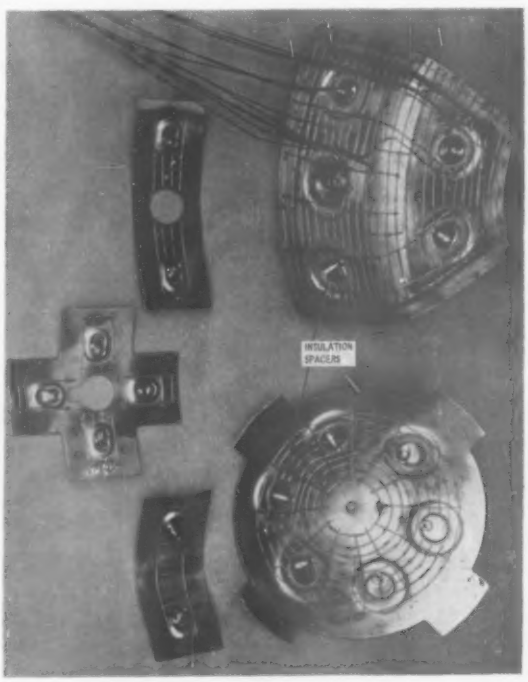


Fig. 19—Hot cover sheets

was finally rectified by employing an eddy current gage. A probe was made for this instrument to bottom against the base of the spacer. Calibration of needle deflection vs. air gap was made and is shown in Fig. 20. Prior to making a weld, the welding operator would use this instrument to measure the air gap between the spacer and the structural wall as shown in Fig. 21. If the air gap exceeded 0.002 in., an auxiliary compressive clamping fixture was used to reduce this air gap clearance to a maximum of 0.002 in. after which the welding operations would then be carried out as shown in the lead photograph.

The forward and tail sections of the C-C tank were similar in design with the forward section shown in Fig. 22. A photograph of the island coupled to the forward section is depicted in Fig. 23, and the final assembly of the forward section, island and tail section is shown in Fig. 24.

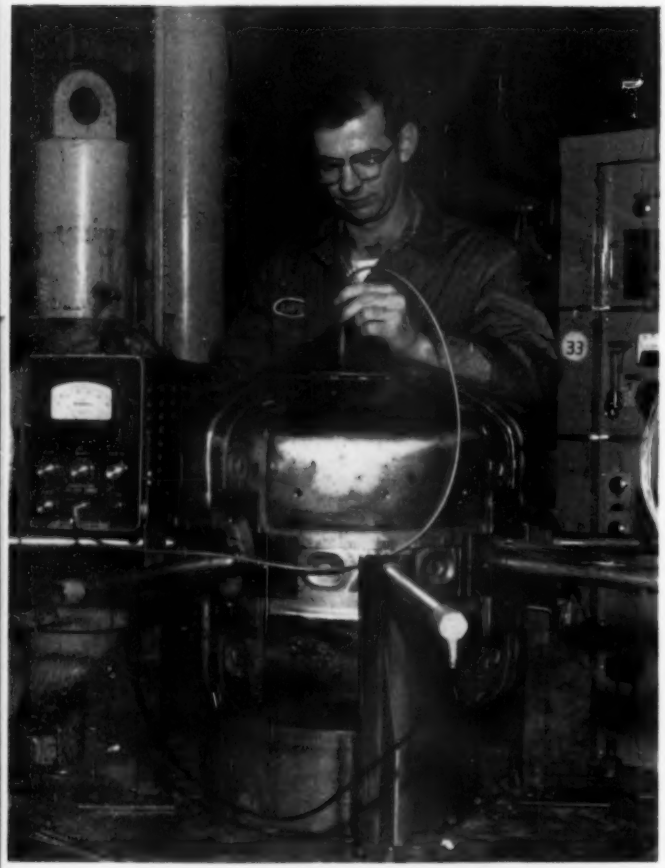


Fig. 21—Measuring of air gap between spacer and structural wall with eddy current instrument prior to welding

Conclusion

In the data presented in this paper, the authors believe that it has been shown that it is feasible and practical to insulate the hot ducting on an aircraft nuclear power plant for service temperatures of 1600° F and service life of several hundred hours. The gas tungsten-arc spot-welding process gives greater reliability when employed for joining the insulation spacer to the structural wall, as compared to resistance and arc stud welding.

It is the opinion of the authors that the welding techniques and procedures developed for attachment of the hot cover sheet to the structural wall could be applied to several different varieties of deep hole welding operations.

Acknowledgment

The data described here were developed under controls of the Atomic Energy Commission and the United States Air Force. The authors wish to thank Messrs. L. V. Owen and E. Westendorf for their recommendations. The authors are particularly indebted to Willard Lewis for his capable efforts in the experimental welding investigation. Acknowledgment is also due to H. Keck for machining the hundreds of weld sample specimens, to Ivan Miller for the metallography work, to Messrs. R. Pucci and J. Reagan for the photography work and to Carl Sipol for the art work.

References

1. Hackman, R. L., "Inert Gas Spot Welding in the Aircraft and Missile Industry," WELDING JOURNAL, **40**, 25–33 (1961).
2. Rowlands, E. W., Jr., and Cooksey, J. C., "Internal Welding of Tubes to Tube Sheets," *Ibid.*, **39**, 704–710 (1960).
3. Bennett, R. W., "Power Pipe Joints," *Ibid.*, **38**, 1175–1181 (1959).
4. Copleston, F. W., and Gourd, L. M., "Developments in the Inert-Gas Tungsten-Arc Fusion Spotwelding Process," *Brit. Weld. Jnl.*, **5**, 394–399 (1958).

Fig. 22—Forward section of the C-C tank

Fig. 23—Island coupled to the forward section

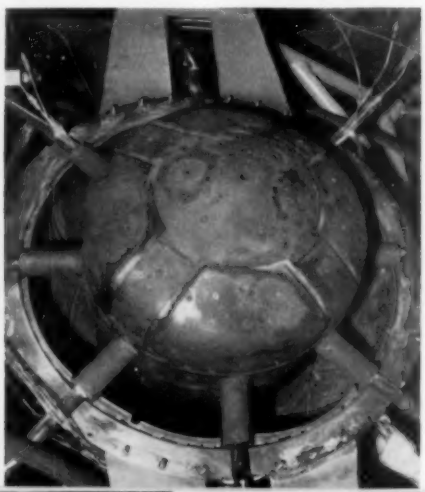
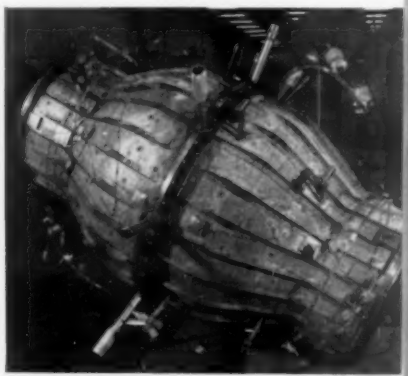


Fig. 24—Final assembly of the C-C tank



An early model—electropneumatic taper control with components for instrumentation

A **Double-Taper** Tungsten-arc Welding Control

is devised to eliminate weld craters and to improve weld appearance as well as to meet metallurgical and weld penetration requirements for specific applications

BY A. DIXON

Improvements in manufacturing methods are favorably influenced by many factors to aid industrial progress. New products and materials are continually presenting problems, often having more precise requirements for their fabrication. Frequently a new process may involve operations which are not easily facilitated in an acceptable manner by manual methods. In welding, as in other manufacturing processes, the rising labor cost has been a challenge to improve manufacturing methods to keep pace with open market competition. It is, therefore, becoming increasingly important to meet this challenge, and the reduction of direct labor in fabricating a product by automating operations is a helpful approach. In welding much can be done with low cost control systems which usually present little or no problem for equipment justification. The apparatus described in this paper is, in fact, an evolution of practical control improvements in the endeavor to promote gas tungsten-arc welding for more economic and versatile utilization.

One primary requirement in many present day applications of tungsten-arc welding, and one to which this effort was directed, is to taper the weld arc at the terminating period in the welding cycle. This purpose is generally to eliminate weld craters and improve the appearance of the weld structure. There are, however, some other cases where a tapering arc and its corresponding thermal effect are used to meet metallurgical and weld penetration requirements for the particular application involved. Some other general and special functions which can be automated for the tungsten-arc process are more familiar and include:

1. Apply inert gas and water coolant to components in the welding circuit and fixtures.
2. Establish the weld arc to the correct electrical operating level for acceptable welding conditions. This is later referred to as a "controlled start" feature.
3. Initiate and direct the movement of the work or welding torch.
4. Program the amplitude of weld current and thermal input in defined preset periods to control fusion of the metal.
5. Extinguish the weld arc.
6. Post-purge, which includes the continued flow of inert gas over the work and the flow of water coolant in the welding circuit for a timed interval after the weld.
7. Reset the taper function and other electric control components in preparation for the next weld.

It is readily accepted that many of these functions can be performed manually in proper sequence by an experienced operator. However, the consistency and reproducibility, weld for weld, is generally questionable by manual methods and, in some cases, the rapid sequencing of functions and thermal requirements for an acceptable weld cannot be properly met unless some degree of automatic control is used. It was this combination of problems that lead to the development of the double taper control.

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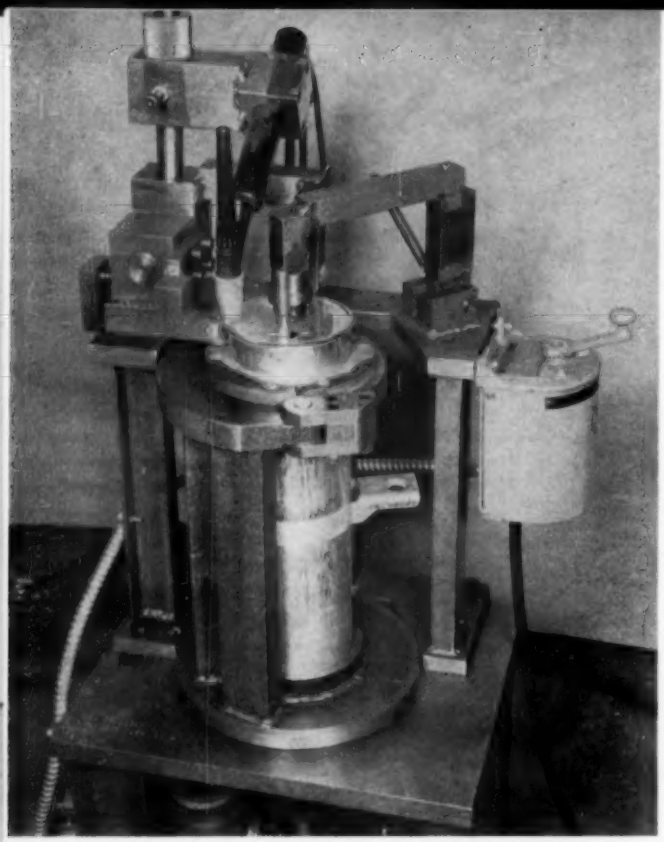


Fig. 1—Rotating fixture for tungsten arc welding cover plates on aluminum capacitor cans

Electromechanical Taper—A Preliminary Model

Several years ago, an improvement in the design for an industrial capacitor housing involved the use of cylindrical aluminum cans. The welding of end cover plates was required to form a hermetically sealed unit. Another requirement was for a smooth surface appearance with no irregularities in the weld. Development of automatic techniques for this operation was justified. A turntable type fixture shown in Fig. 1 was designed for rotating the cans with the welding torch in a fixed position. The power source was a direct current welding machine having a transformer with a movable iron core for current adjustment.

Practical objectives were followed in a control design to use low cost, reliable components. For example, where noncritical time delay functions were required, pneumatic relays were used. The critical timing periods were controlled by synchronous motor driven relays. Standard parts were used throughout. After the operator initiates the welding cycle, microswitches actuate the control functions in correct chronological and progressive sequence as the can rotates in the fixture.

Figure 2 is a schematic diagram showing the circuitry involved. During the welding cycle, the work makes two complete revolutions to an indexing point for loading and unloading the fixture. The

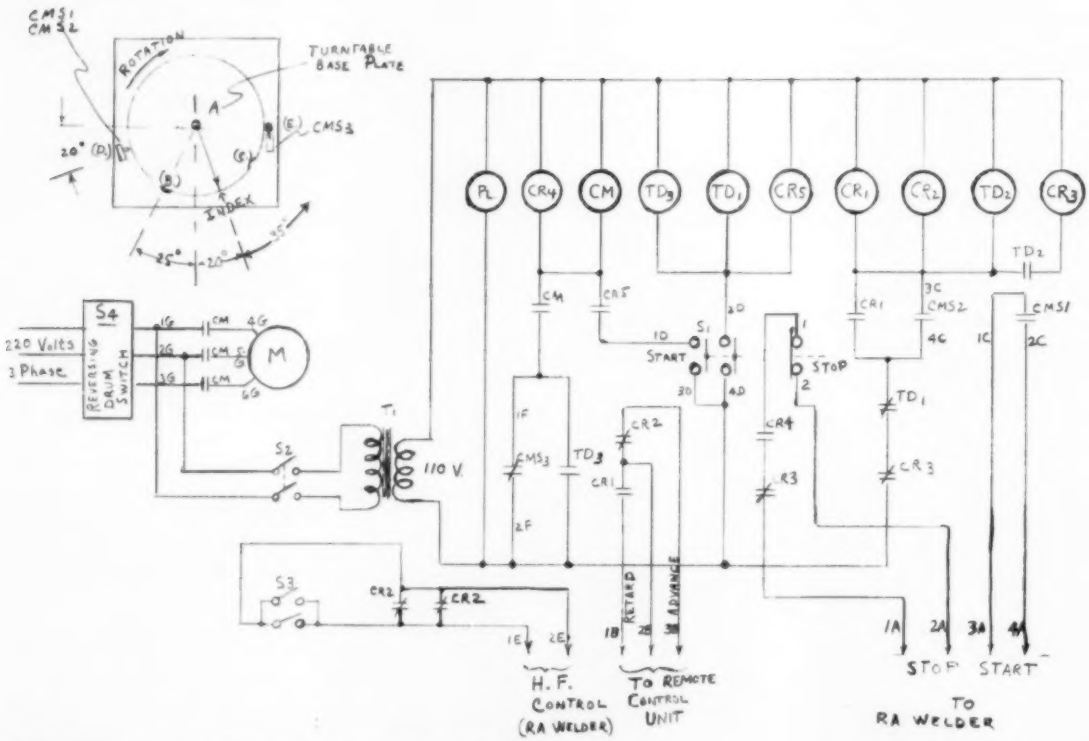


Fig. 2—A schematic of the electromechanical taper control using a moving iron core in the welder transformer for current adjustment

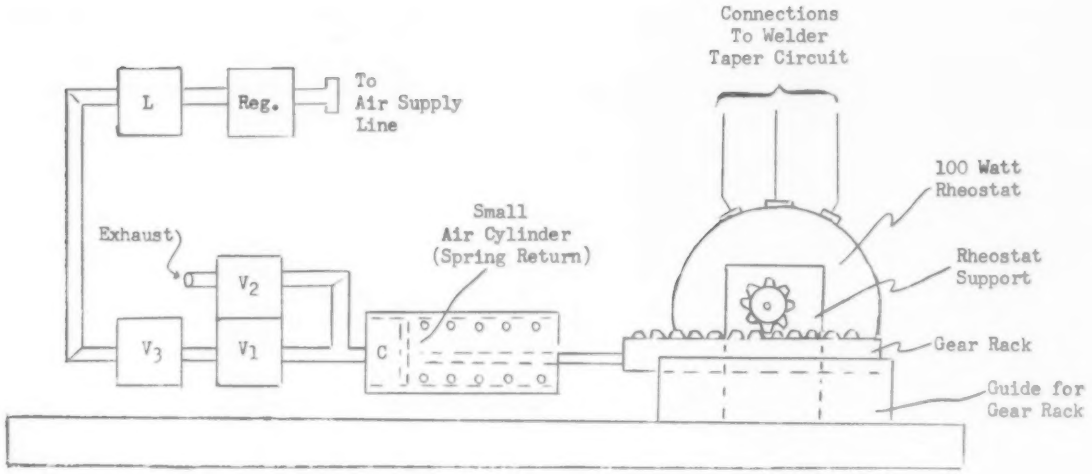


Fig. 3—Electropneumatic current tapering mechanism

Reg.—Line 80#/30# Air Regulator / Wesco Machine Products Inc. SPIO airline filter,
L—Air-line Lubricator \ Philadelphia, Pa. automatic lubricator
V_1—Breckett-Harcum 1/8" Type BVP-1 3-way valve and pressure regulator
V_2 to operate on 110 volts, 60 cycles. assembly.
V_3—No. 2 Speed Control Valve (Mead Co.) / Armen H. Willie & Assoc.
C—Air Cylinder—Type HIX-23 (2 to 3 in. \ Pittsburgh, Pa.
Horizontal stroke) Mead Co.

main weld is made during the first revolution, and the taper period during the second. Microswitch (CMS_1) initiates the high-frequency and the weld arc. After completing the second revolution, microswitch (CMS_3) extinguishes the weld arc and resets the control for the next weld. (The action of microswitch (CMS_3) is blocked during the first revolution of the work by time delay relay (TD_3).) High-frequency stabilizing voltage is removed at the start of the second revolution and taper period by contactor relay (CR_2). This feature was desirable to produce a high quality mark-free appearance at the termination of the weld.

The actual period of arc taper is initiated by the closing of microswitch (CMS_2) in Fig. 2 at the start of the second revolution of the work. A time delay relay function is used to block the taper initiation during the first work revolution. Tapering of the weld current is produced by a motor raising the iron core in the welder transformer. This regulates the current between maximum (weld current level) and minimum (taper current). Operating limits of motor travel are preset by means of microswitches and adjustable cams which rotate with the drive motor. Contactor relay (CR_1) operated to retard the current during the taper period. Relay (CR_2) advances the current control to the normal welding level at the termination of the weld cycle in preparation for the next weld.

For welding end covers on 4 3/8 in. diam aluminum cans, this automated operation enabled a welding speed of 41 ipm with helium gas coverage at 20 cfh. Direct current, straight polarity current was used at 130 amp for the main weld. The taper period was 9 sec to a final current of 40 amp. The welding torch used a 3/32 in. diam, 2% thoriated tungsten electrode. Favorable production rates were attained with a reported savings in excess of 30% over manual welding. On the other hand, the system was not as maintenance-free as previously anticipated, and occasional replacement of thrust bearings in the taper core adjuster motor was necessary. Relay contacts were dressed and cleaned at two week intervals and were relatively trouble free.

Electropneumatic Taper—An Intermediate Model

As the work progressed in the applications to follow, the limitations in the first prototype (the electromechanical unit), which produced a fixed taper period as dictated by the gear motor drive of the iron core current adjuster, had proved too slow. It was then necessary to provide a taper function which would have a faster response and enable the variable selection of taper time as well as final taper current. The saturable reactor type current control had this flexibility and was adapted to operate by means of a rheostat coupled to the thrust arm of an air cylinder. This is shown in Fig. 3. A speed valve (V_3) is used to attenuate the air flow and provide a variable taper timing period. Saturable reactor control eliminated the previous problem of bearing wear in the electromechanical system.

A specific welding application having these taper requirements is a tube-to-sheet weld for a heat exchanger. In this case a small rotary type tungsten arc torch was used to make a circumferential weld of the tube to the header plate. To produce ac-

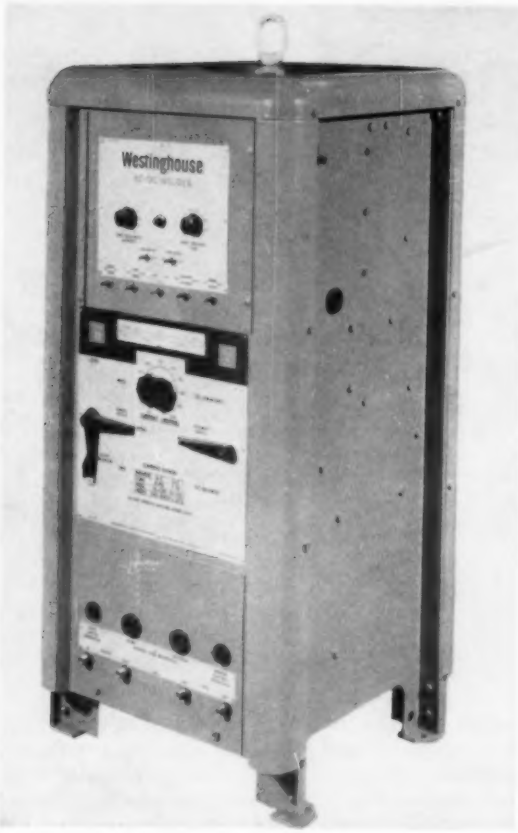


Fig. 4—A typical welder power source with saturable reactor control

ceptable welded joints, the taper period is necessarily limited to less than 2 sec. Electropneumatic arc taper can be conveniently adapted for use with a standard direct current rectifier type power source having saturable reactor type current control. Welding machines are commercially available with this feature. The only modification which may be necessary is to provide a rheostat having electrical resistance and power rating according to the control requirements of the particular saturable reactor machine. This information can be obtained from the welding equipment manufacturer. A typical power source with saturable reactor control for use with this system is shown in Fig. 4.

Other Control Improvements

During this period of development, some work having critical requirements was being done on circumferential welds where maintaining consistency in starting the weld arc was a problem. The operation was automated with the work being rotated and the welding torch stationary. After the operator initiated the weld cycle, the operational sequence followed through, irrespective of weld arc conditions. This meant that if the weld arc did not properly establish at the beginning of the weld cycle, the actual fusion started too late and only a partial weld was made. This defect varied according to the delay before proper arc conditions were established. When an attempt was made to repair unwelded areas, excessive penetration generally occurred in the over-weld areas and was not acceptable. It was, therefore, necessary to make the work rotation and welding sequence contingent upon proper electric condition of the weld arc.

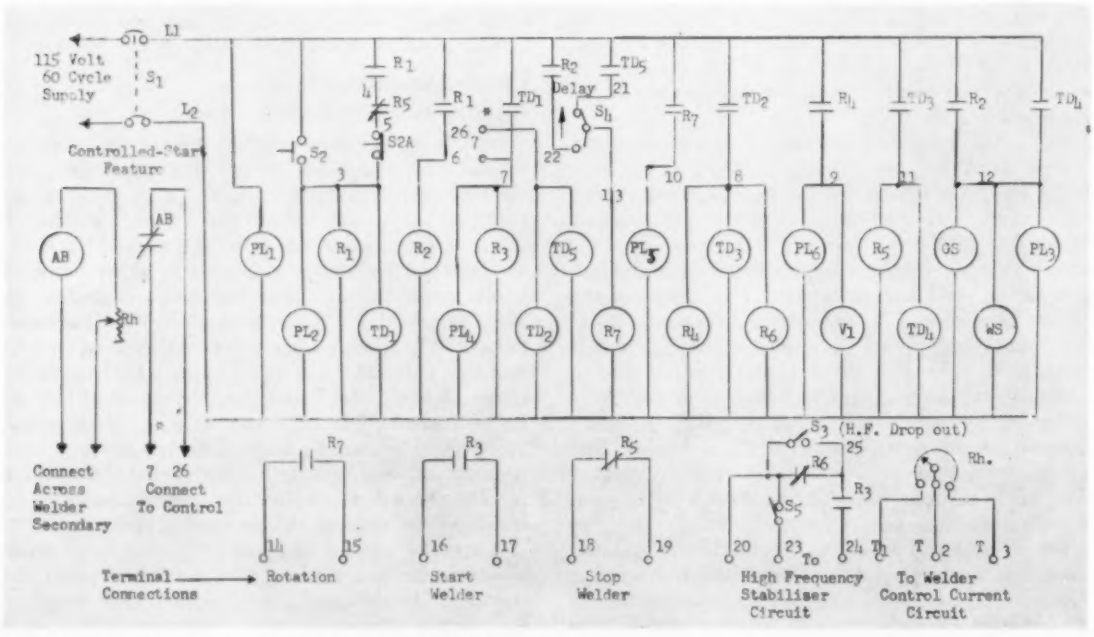


Fig. 5—A schematic diagram of the electropneumatic taper system

A solution to the arc starting problem (later referred to as a "controlled start feature") was made possible by the use of a voltage sensing relay connected across the direct current output circuit of the welding machine to the torch and work. This is shown in Fig. 5 along with complete circuitry for the electropneumatic control. The voltage sensing relay operates to close when an open circuit or high impedance voltage appears at the welding torch. When the arc is struck, the direct current voltage at the torch drops to the normal weld arc value, actually below that point at which the relay opens. At the start of each weld cycle, the full open circuit voltage appears across the relay; its closing action blocks the operational sequence until a low impedance or normal weld arc is established. The rheostat (RH) is provided for adjusting the pull-in and drop-out voltage points for the relay operation, according to the dynamic characteristic of the welder machine. It should be noted, however, that there are two methods of connection for the coil circuit of the voltage sensing relay. Where the welding installation does not include a high-frequency arc stabilizer, the connection is made directly to the torch or "electrode" lead from the welding machine. If a stabilizer is used, it is necessary to bypass the high-frequency voltage and connect directly to the "electrode" terminal on the welder machine.

Another problem previously encountered in the tungsten-arc welding of aluminum and some other metals is in minor pitting and marking on the surface of the weld, caused by the discharge and impingement of high-frequency voltage peaks. It is particularly noticeable on welding of light gage materials where relatively low current weld arcs are used. This also includes the arc taper period where the weld current is progressively attenuated and reduced by a substantial amount. In tungsten-arc welding where high-frequency voltage is used for arc starting or stabilizing, this problem can be eliminated by a control feature to remove the high-frequency at definite periods during the weld cycle. In almost every case, this will include the arc taper period. However, it may—in the case of low current requirements for welding—include the full weld cycle after the arc is established.

These features are included in the circuitry shown in Fig. 5. The relay (R_6) operates to remove the high frequency for the taper period, after the completion of the main weld. In order to limit the use of high-frequency exclusively to the starting of the weld arc, a current relay is used (not shown in Fig. 5) which operates from actual weld current flow. Normally closed contacts on this relay apply high-frequency voltage at the very initial start period when no current is flowing to the weld arc. After normal current flows in the welding circuit, the relay is energized and its contacts open which remove the high-frequency voltage.

In some special work on the tungsten-arc welding of stainless steel, it had become necessary to provide an additional time delay control to withhold rotation of the workpiece for a preselected time after starting to insure proper fusion. This feature, provided by control relay TD_5 in Fig. 5 sparked a later idea to provide separate arc current periods of selective duration. This operating principle was incorporated in the control circuit using the double taper principle. An early model of the electropneumatic control is shown in the lead photograph. This unit contains current shunts and other additional components for instrumentation of the weld arc current and voltage.

Independent Arc Control Periods—The Double Taper Function

It was found necessary at this stage of development to give special consideration to controlling the thermal intensity (current amplitude and time) of the weld arc for specific periods in a given welding cycle. They were defined as (*a*) starting the weld arc, (*b*) nominal or main weld arc and (*c*) final or tapering arc period. Welding requirements were analyzed and classified in two functional groups, which were found to cover many broad areas of application:

Welding Condition I

Consider a welding operation where a weld arc of low intensity is necessary at the start period and for a preset interval thereafter to avoid melting thin sections on the workpiece. The initiation and control of movement for the torch and/or work will require a properly established weld arc and its correct thermal condition. A second period of arc intensity at a different current level is required for the nominal or main weld. After the weld is complete, a tapering weld arc to a lower intensity is needed for reduction or elimination of weld crater. Postpurging with the flow of water and shielding gas is required for several seconds at the conclusion of the weld.

Welding Condition II

In contrast to Condition I, consider another welding operation where a relatively high arc current density is initially required to promote arc starting and/or fusion. Examples of this are (*a*) in a vacuum chamber where arc starting is difficult, and (*b*) where the start of the weld is on or adjacent to materials having a relatively high thermal conductivity and additional heat is required. A second preset period of weld arc intensity for nominal weld current (usually lower value) and a third period for arc tapering to reduce or eliminate craters. Condition II will also require the controlled start feature as in Condition I. Postpurging of water and shielding gas is required.

In the double taper system, control adjustments are provided for presetting both the current amplitude and time interval for the three independent periods of weld arc intensity. In this manner it is possible to select an operating sequence to meet the specific group of welding conditions needed for a

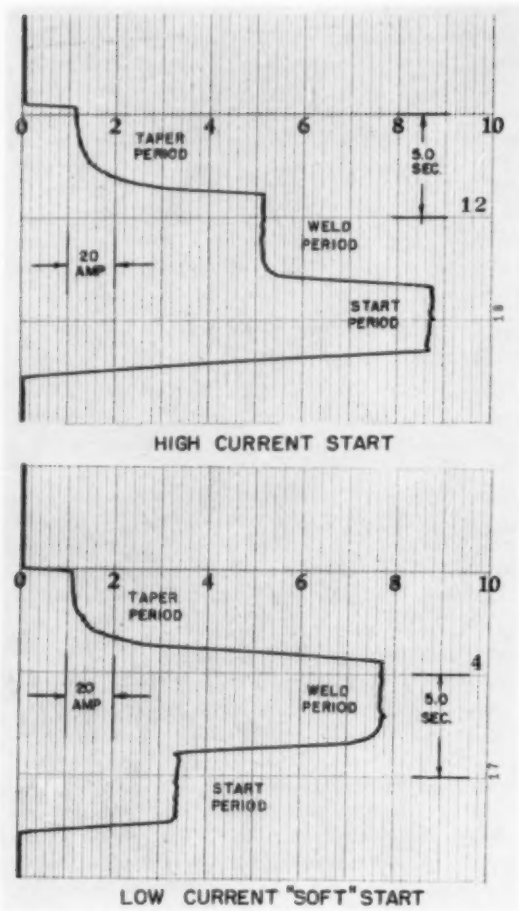


Fig. 6—Typical welding current cycles for the double taper control

particular job. The oscillograms shown in Fig. 6 illustrate typical current cycles for welding programs as defined in operating Condition I and II. The double tapering action is clearly shown in Trace A (top oscillogram). This represents a high current start at approximately 175 amp. Trace B (lower oscillogram, Fig. 6) is a "soft" or a low current start at approximately 70 amp. The maximum chart scale for this measurement is 200 amp, direct current. The dwell time for each period is on the order of 5 sec. However, in an actual welding operation, the dwell time would be adjusted to render correct thermal conditions for the specific requirements of the application. It should be noted that the more rapid up-slope response at higher current levels is desirable to promote consistency in arc starting and initial fusion whereas the current decay is retarded at lower levels, giving a more desirable heat quenching action at the termination of the weld. The final current can, however, be retained at an attenuated level for an extended period where desirable to improve metallurgical properties of the weld.

Many of the standard features previously described were incorporated in the double taper control package. Dwell periods for weld current output are programmed according to specific requirements for the weld. The corresponding current output is directed by circuits to provide sequence of current control, also in accordance with the maximum weld values of the particular job being considered. Figures 7 and 8 show the double taper control unit.

Conclusion

Examples of functional control methods in this paper illustrate how low cost automation principles are being applied to the inert-gas-shielded tungsten-arc welding process. Production proved, the use of these techniques are enabling substantial savings in manufacturing costs with considerable improvement in weld and product quality. Experience has shown that, in other cases, exacting weld requirements were attained which could not be satisfactorily accomplished by existing methods. In this manner, the double taper control principle is serving the tungsten-arc process and presenting a wide degree of utilization for an increasing number of welding applications.

Fig. 7—The double taper control—external view

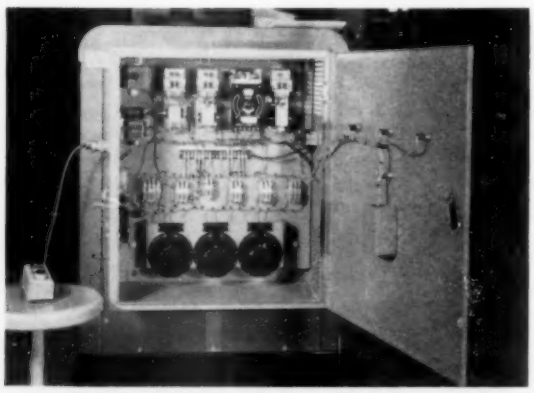
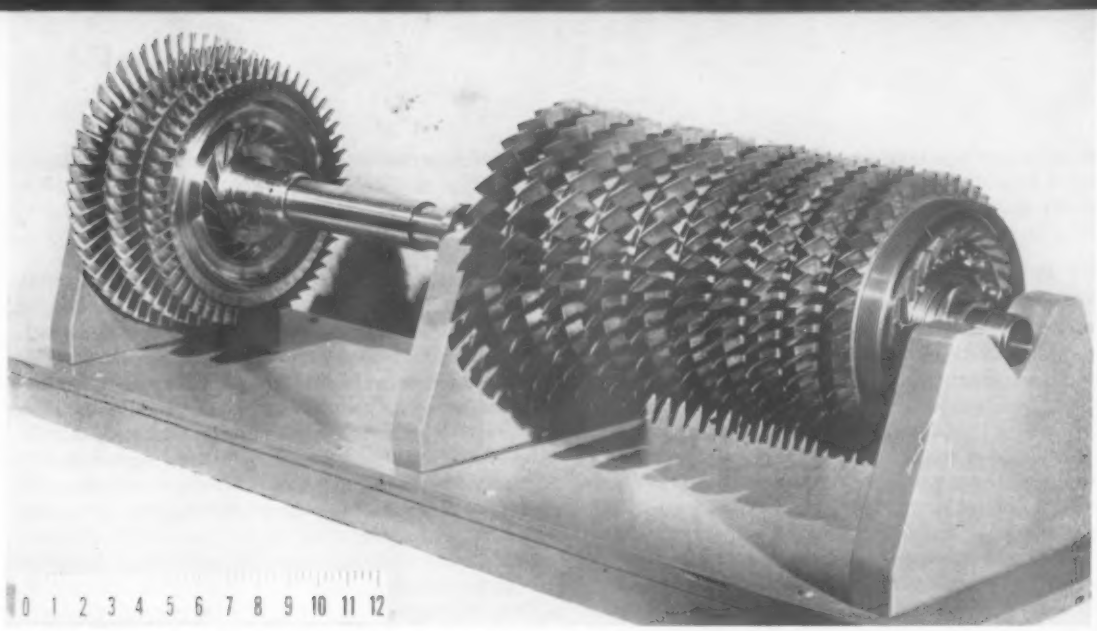


Fig. 8—The double taper control—inside view



Compressor and turbine blades for small gas-turbine engine as assembled by argon brazing

The elimination of repurification units, faster heating and cooling compared to vacuum, and an explosion-proof medium are featured in

High-Purity Argon

Protects Difficult-To-Braze Metals

BY J. W. HILL

Introduction

Brazing may be defined as the joining of two, not necessarily similar, base metals with a brazing alloy; this process takes place at temperatures below the solidus of the base materials. To produce an acceptable joint, the liquified brazing alloy must "wet" and flow over the base metals in the joint area. Oxides and other surface films on the base metal either interfere with or prevent this wetting and flow. Before the braze joint can be made, therefore, it is necessary to remove existing surface films and prevent the formation of new ones. Traditionally, this has been the major purpose of the brazing flux.

However, it is not always feasible, or even possible, to use a flux when brazing. Certain part configurations make post-braze flux removal extremely difficult, and at times impossible. Since flux residues are a corrosion hazard and can cause other problems, some alternate form of surface protection during brazing becomes necessary.

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Many of the fluxless brazes, demanded by designers today, involve the use of superalloys. Highly reactive components in these superalloys react to form surface films at high temperature exposure to even traces of atmospheric contaminants such as oxygen and moisture. These continuous, adherent films are very difficult to remove and interfere with braze alloy wetting and flow. Purity of atmospheres for protecting these metals is thus a critical consideration.

Surface Protection for Fluxless Brazing

Surface protection for fluxless brazing of the difficult-to-braze metals usually takes one of three forms:

1. Hydrogen—most commonly used of the reactive or reducing atmospheres
2. Vacuum.
3. Argon—most commonly used of the truly inert gases (with helium a possible alternative).

The effectiveness of each of these environments depends upon the degree of freedom provided at the joint surfaces from contaminants which cause undesirable surface reactions. Although each environment has an area for which it is best suited, there is

considerable overlapping. Before presenting a detailed consideration of argon atmospheres, it is well briefly to enumerate and compare the major advantages and disadvantages of each system.

Hydrogen

For many years, combustion-type gas generators have provided atmospheric protection for nonferrous materials and carbon steels, while hydrogen or high hydrogen mixtures have been used with stainless steels and other more difficult-to-braze materials. Because of this, industry has long been familiar with hydrogen and recognizes it as a relatively inexpensive and flexible protective atmosphere. Since hydrogen exhibits high thermal conductivity, its use results in rapid heating and cooling rates.

Hydrogen's most important advantage is its ability, when sufficiently free of oxygen and moisture, to reduce iron, nickel and even chromium oxides. Relatively simple and efficient gas purifiers are available to lower the oxygen and moisture content of commercial hydrogen; and purified hydrogen will actually clean up the oxide films on standard stainless steels during bright annealing and brazing. This has been hydrogen's area of greatest usefulness even though purifiers are generally required. In addition to increasing the cost and complexity of the operation, purifiers must be regenerated periodically and are subject to poisoning and malfunction. Only with adequate gas-analysis instrumentation is the hydrogen user assured that his purifier is functioning correctly. Many users accept the hazard of occasional malfunction rather than provide the insurance of instrumentation.

Hydrogen, however, will not reduce the oxides of such metals as beryllium, magnesium, hafnium, lithium, aluminum, zirconium and titanium. Therefore, hydrogen cannot remove oxides from these metals nor can it clean the superalloy which contains one or more of these elements. With these materials hydrogen's principal advantage is lost, while the liabilities which accompany its reactivity are retained or enhanced.

For example, hydrogen may act as a carrier for oxygen by reduction of one oxide at the expense of forming another. Reduction of oxides of nonreactive metals present anywhere within the system (on retort walls, jigs, etc.) increases the moisture content of the hydrogen. This results in further oxidation of the more reactive metals by this moisture. Similarly, hydrogen may carry carbon from areas of high concentration (graphite fixtures, carbon steel retorts, etc.) to areas of low concentration such as a stainless steel workpiece. The result may be embrittlement or other property impairment of the base metal.

Since hydrogen can cause embrittlement of such reactive metals as columbium, hafnium, tantalum, titanium, vanadium and zirconium; hydrogen is immediately eliminated as an atmosphere choice. Also, in many steel applications the fear of hydrogen embrittlement or other property damage prevents its use.

Hydrogen's ever present explosion hazard demands particular vigilance and careful attention to safety precautions.

Vacuum

The most important advantage of a good vacuum system is its inertness or freedom from contamination. In theory, a well designed, carefully constructed, continuously maintained, efficiently operated, and effectively "gettered" vacuum system when repeatedly evacuated and backfilled with a high-purity inert gas offers the lowest obtainable level of contamination. However, such ultimate purity levels are difficult to obtain in small laboratory installations and are seldom encountered on a commercial level.

While vacuum is compatible with all materials and able to provide substantial surface protection for the fluxless brazing of the superalloys, vacuum cannot be used with materials which have a high vapor pressure. Excessive vaporization loss of a volatile component can result when this point is ignored.

One of vacuum's more convenient advantages—often misinterpreted or abused—is that a combined knowledge of both leak rate (representing throughput) and the pressure existing *in the area of interest* (representing residual contamination) gives an indication of relative contamination. Disregarding or forgetting the full importance of *both* these factors results in an erroneous indication of the contamination level.

A high capacity pumping system, for instance, can maintain a low instantaneous pressure, even in a chamber whose leak rate at elevated temperatures is high. Thus, knowledge of pressure alone indicates a low level of instantaneous contamination, while the part may actually be exposed to a large cumulative amount of contamination. This occurs because each contaminant molecule which reacts at the part surface is replaced by a new contaminant molecule from the leak. The high mean free path of molecules within the vacuum system increases the probability that an entering contaminant molecule will reach the part before it is removed by the pumping system.

It must also be remembered that the contamination level in the braze area is indicated by the pressure in that same area. The pressure in this area will be greater than that at the mouth of the diffusion pump. The pressure gradient between these two points will be increased by complexities in the vacuum system (bends, valves, small aperatures, etc.). Only in a well-designed vacuum system having a small pressure gradient will a pressure sensing device placed next to the diffusion pump give an accurate indication of the pressure existing in the braze area. Frequently, when poor or medicore results are reported as having been obtained at very low pressures, it has been found that these pressures were recorded next to the diffusion pump. Much greater pressures or contamination levels probably existed at the part area.

Vacuum systems, however, require elaborate furnace and/or retort structures. These structures

must withstand a pressure differential approaching 1 atmosphere, or, more than 1 ton per sq ft. To withstand this pressure at brazing temperature requires heavy, massive equipment.

Argon

Argon, like hydrogen, offers a convenient and flexible protection system with a much lower capital investment than vacuum. Because the gas atmosphere enclosure is subjected to only a slight pressure differential, the equipment may be much simpler and lighter than that used with vacuum.

Argon is available in any commercial quantity at a guaranteed as-delivered purity of 99.996%, or no more than 40 ppm total impurities. Actual analyses show that the delivered purity is on the average considerably better than the guarantee. Unlike hydrogen, argon, in general, does not require further purification by the user. The uncertainties which accompany some repurification units and the loss of product resulting from their malfunction are also eliminated.

Argon also offers more rapid heating and cooling rates than possible with vacuum. In this connection argon is used for backfilling hot vacuum retorts and serves as an aid in heat transfer during the cooling cycle.

Because argon is truly inert, it is compatible with all materials, offers no explosion hazard, and eliminates the possibility of oxygen or carbon migration by gas reaction. While argon will not reduce oxides, neither will hydrogen reduce the reactive-metal oxides found on the superalloys. It is, therefore, with these very difficult-to-braze alloys that argon finds its area of greatest usefulness.

Fluxless Brazing in Argon Atmospheres

The first major commercial utilization of argon as an atmosphere for fluxless brazing was in the production of honeycomb panels for high temperature aircraft usage. These panels, whose configuration prohibits the use of flux, must be constructed of superalloys to meet high-temperature strength requirements. Surface protection of superalloys is difficult and demands low over-all contamination. Hydrogen was not used in this work because its reactivity could cause oxygen and carbon migration. The extensive use of vacuum in this field would have required new, large, expensive installations. A high capital risk was involved since a governmental cutback on aircraft expenditures could (and did) severely limit the originally visualized honeycomb market. This produced a strong incentive toward the use of existing furnaces, or inexpensively constructed new ones, and favored the use of inert atmospheres.

Feasibility studies in aircraft industry laboratories proved that argon could provide an excellent atmosphere for honeycomb brazing of superalloys. In the changeover from laboratory to full-scale production of honeycomb panels, however, some difficulties were encountered in establishing and maintaining the required low level of contamination in the braze area.

Implemented by gas analysis equipment which could detect contaminants in the parts per million range, field development effort demonstrated that there were in general three problem areas:

1. Contamination during piping and distribution.
2. Contamination resulting from use of so-called gas purifiers.
3. Residual contamination within the retort

The solutions to these problems are not difficult. Since the general problems of gas purity are so important in the field of fluxless, atmosphere brazing, however, a detailed analysis of purity maintenance is in order. Although the principles outlined for the maintenance of purity refer specifically to argon, they apply to any inert, nonreactive, or reactive gas and are generally applicable to vacuum systems.

Maintaining Gas Purity during In-Plant Distribution

As previously stated, argon can be delivered to industrial gas users at an exceptionally high purity level. When a high-purity gas is required, however, it is necessary not only to acquire it in an ultrapure state but to maintain that purity to the use-point in the plant. The standards of gas purity required by reactive metals and superalloys go far beyond the experience of the average metal fabricator or plant pipe fitter. Many common gas-conveying materials and techniques are entirely inadequate for maintaining an uncontaminated atmosphere. New standards of gas purity require new quality control standards. A "leak-tight" line which is perfectly satisfactory for welding oxygen or acetylene service may allow gross contamination of a gas for high-purity service. The difference here is one of degree. An amount of contamination which would go unnoticed in standard gas processes can spell failure for a process demanding high purity.

This does not imply that the maintenance of gas purity during distribution is unduly difficult. With proper gas handling equipment and procedures, it is a straightforward matter to maintain as-delivered purity throughout in-plant distribution lines.

An in-plant gas distribution system usually consists of piping, valves, regulators, flowmeters, flexible tubing, hose, gaskets, fittings and other hardware. Each of these items is a possible source of contamination. The components of a high-purity gas system must, therefore, be carefully chosen and installed to eliminate or at least minimize contamination.

The major source of contamination during in-plant distribution is the continuous entrance of contaminants from outside the system by:

1. Leaks or diffusion through holes, cracks and/or porous materials.
2. Permeation through materials such as rubber and plastics.

Leaks and Diffusion

As a matter of principle, everyone agrees that a

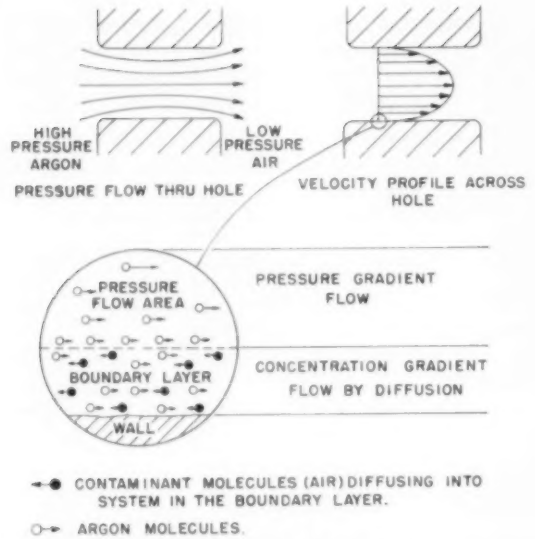


Fig. 1—Reverse flow diffusion at the boundary layer of a pressure leak

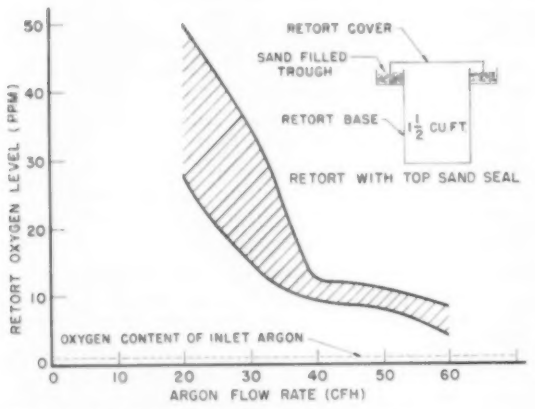


Fig. 2—Variation of oxygen level with argon flow rate in a sand seal retort

leak-free gas system is desirable. Since gas will flow from an area of high to low pressure, it is especially important that leaks be eliminated when the high-purity argon system is at lower pressure than the surrounding atmosphere. A familiar example of such a case is the usual honeycomb brazing retort. A slightly reduced pressure is maintained within the retort to utilize external gas pressure as a clamping or holding mechanism. If a leak should develop in such a system, the pressure differential would cause external contaminants to flow into the high-purity system and ruin the braze. It thus becomes obvious why extreme care is taken to eliminate leaks in any reduced pressure or vacuum system.

In the past, slight leaks in *pressurized* systems have not usually caused much concern. A leak in a pressurized line has generally been considered to act as a one-way street. It is often suggested that, although some process gas may exit through a leak, no contamination will enter as long as a "positive pressure" exists in the system. This is not entirely true.

While gas normally flows from an area of high to low pressure, it is an important but often ignored fact that gas movement is also governed by concentration differences. When a gas component exists at two different concentration levels in connected areas, it will flow by diffusion from the area of high to low concentration. It is an established fact that this will occur—even against an absolute pressure differential. For example, if pressure and concentration gradients call for flow in opposing directions, a high-velocity pressure flow will tend to offset an opposing concentration flow although it cannot entirely eliminate it.

In the case of a gas-system leak, an additional factor favors concentration flow. This is easily understood by consideration of the velocity profile of pressure dependent flow through a small opening as illustrated in Fig. 1. The velocity of gas particles through an opening is not uniform across the entire section. Gas at the center of the stream travels at high velocity. Gas in the boundary layer near the periphery or walls of the opening moves much slower, while gas immediately adjacent to the walls is considered to be static. Consequently, in the region close to the wall, conditions greatly favor the occurence of diffusion flow.

Leaks in gas systems very often take the form of small cracks. When these cracks are small enough to escape notice during standard inspection, the proportion of boundary-layer area to total opening area is large and thus the proportion of diffusion flow is large. It is, therefore, easy to understand how even the tiniest crack can add several parts per million of contamination to a high-purity gas.

Porous materials provide another path for contaminant influx by diffusion flow. A porous barrier frequently encountered in standard brazing retorts is the sand seal. Such a seal is made by sinking the edges of the retort cover into a sand-filled trough on the retort base. Process gas within the retort is subject to contamination by back diffusion through the sand of contaminant molecules from the outside atmosphere. The rate of contaminant influx through a sand seal is affected by such factors as the flow rate of purge gas, grain size of sand, perimeter of seal, effective area of seal, relative pressure and temperature. Other factors being constant, increasing the flow of purge gas will decrease contamination concentration within the retort by dilution, will increase contaminant removal rate, and will reduce back diffusion. High purge-gas flows are required, however, to attain a relatively low level of contamination. Figure 2 illustrates the relation between argon flow rate and oxygen contamination level for a small $1^1/_2$ cu ft retort having a top sand seal. Although the inlet argon contains only 1.2 ppm oxygen, a flow rate of 40 cfh, or more than 26 re-

tort volumes per hour is required to drop the retort oxygen level to 12 ppm. Sand seals can only be successfully used where high purge-gas flows and/or relatively high contamination levels can be tolerated. Critical applications require welded or mechanically sealed retorts. All porous materials such as ceramic tubes and graphite-asbestos valve packings must be recognized as contaminant sources and excluded from a high-purity gas system.

Permeation

Permeable materials allow gas or vapor molecules to penetrate and travel through their structures. Rubber and plastics are the permeable materials of most concern. Serious contamination of high-purity gas can result from use of these materials. For example, substantial amounts of oxygen, nitrogen, moisture and other atmospheric contaminants will penetrate the walls of perfectly sound, leak-free rubber hose and contaminate an internal high-purity gas.

The mechanism of permeation is one of adsorption of gas or vapor molecules on one side of the material, solution in, diffusion through, and evolution at the other side of the material. Concentration or pressure gradients across the material provide the driving force. Since argon can be supplied with a very low impurity content, it can be seen that a strong concentration gradient will exist between it and the atmosphere.

The rate at which permeation occurs is strongly dependent on the nature of the contaminant and the material in question. While permeability varies greatly, plastics are in general less permeable than rubber.

The use of permeable materials should be eliminated if possible or at least minimized. However, where these materials must be used, as for electrical insulation, the least permeable material should be chosen. In addition, the surface area exposed to the high-purity gas should be minimized and the thickest practical section used.

Gas Purifiers

Gas purifiers have little place in a properly designed and constructed high-purity argon distribution system. Since such a system will maintain the as-delivered high purity to the point of use, further purification is unnecessary.

In addition, purifiers may even be undesirable. Because most commercial units are not intended for use with high-purity gas, their internal piping may allow excessive recontamination. The end connections of commercial gas purifiers may be of a type subject to contamination. Depending upon its particular type, a gas purifier may become exhausted, loaded, poisoned or may cease to function for some other reason. In addition to providing a false sense of security, dependence on a purifier can lead to carelessness on the part of operating personnel. Gas purifiers in a high-purity argon system are not normally recommended. They would be at best an expensive attempt to compensate for pipeline inadequacies.

Gas purifiers should be used to reduce the gross amounts of contamination found in generated gas and some cylinder gas such as nonpurified hydrogen. In such applications, purifiers can give creditable service.

Removal of Contamination from the Retort

Discussion has thus far centered mainly around supplying a high-purity gas to the point of entrance to the brazing retort. While this step is very important, it alone cannot assure an acceptable braze joint. It is the atmosphere within the retort, the atmosphere contacting the joint, which must be sufficiently pure to provide the desired protection.

The first step in establishing a high-purity atmosphere within a brazing retort is the "primary purge" or removal of the air originally contained and replacement with argon. In some applications the easiest, most efficient means of accomplishing this step is by displacement purging. Displacement purging capitalizes on the fact that argon is denser than air. With suitable gas introduction, it is possible to minimize gas mixing so that argon entering at the bottom of the retort acts much like a piston displacing the air upwards to be vented at the top. (Displacement purging has been described in a paper presented at the 1960 Electric Furnace Conference.)*

Because a "primary purge" removes the *gaseous* air which originally existed within the retort, it is often assumed that all contamination is removed at the same time. This is untrue. Although gaseous contaminants have been removed, large amounts of contamination in other forms still exist within the retort. The evolution of these contaminants as gas phase impurities is called outgassing. The most important outgassing processes occuring in a brazing retort are:

1. Desorption of absorbed gases and moisture.
2. Volatilization of residual lubricants or cleaning compounds.
3. Decomposition of hydrates possibly present in refractories.
4. Decomposition of organic binders, which are often used with powdered brazing alloys and stopoff compounds.

Contaminants evolve at widely varying rates. The contaminant, its source and the temperature largely determine these rates. Some contamination is quickly evolved and soon removed from the retort, while some may still be present at high temperature, even after extensive purging.

Moisture is a particularly troublesome contaminant because it is difficult to remove from the retort and because it is apowerful oxidant. It may be present in a combined form as a hydrate, absorbed in large quantities within porous materials, and ad-

* M. F. Hoffman, P. G. Bailey, and R. L. W. Holmes, "Argon Casting for Improving Steel Quality," Journal of Metals, **13** (5), 345-349, May 1961.

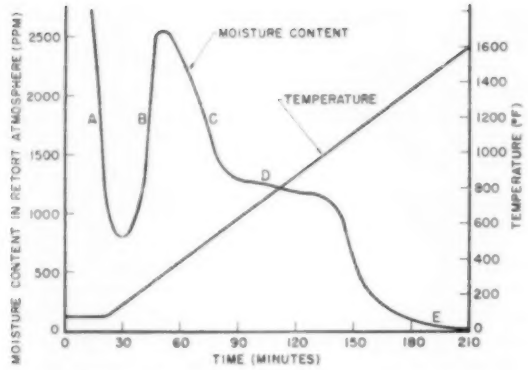


Fig. 3—Variation of moisture content and temperature during a typical braze cycle resulting in unacceptable braze

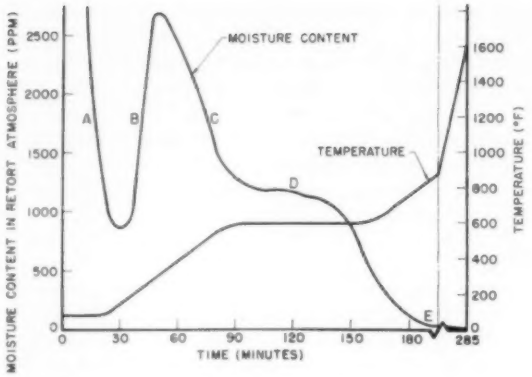


Fig. 4—Acceptable braze achieved by modifying thermal cycle only

sorbed on all surfaces of the retort, part, jigs and fixtures.

To illustrate the difficulty encountered in moisture removal an example of inadequate purging practice is illustrated in Fig. 3. Here is shown the variation of atmosphere moisture content in a test retort undergoing a continuous purge during uniform heating. The stainless steel retort contains a superalloy part supported by a porous refractory fixture. The argon entering the retort contains less than one ppm moisture.

Stage A in Fig. 3 indicates a sharp initial decline in moisture during a room temperature purge. The decline results from replacement with argon of the humid air originally in the retort. This is the primary purge. Because the rate of evolution of moisture is very slow below 200 F, absorbed moisture is substantially unchanged during this period.

As the retort is heated above 200 F, the evolution of all adsorbed moisture becomes much more rapid, and even with the continuous purge, there is a sharp increase in moisture level (Stage B). This moisture is initially present as adsorbed films on the retort and part, as well as within the porous refractory fixture.

As the temperature increases and purging continues, moisture content decreases (Stage C) as the moisture adsorbed on nonporous surfaces is depleted.

A period of relatively constant moisture content (Stage D) follows as the porous material continues to outgas. Large quantities of internal moisture are evolved by such materials at a fairly uniform rate, because evolution is controlled by diffusion from internal surfaces. This evolution can continue long after general surface moisture is depleted.

The moisture content in the atmosphere of the hot retort does not drop to an acceptable low level (Stage E) until all sources of moisture have been depleted. In this case the braze joint reaches a 1000 F, a temperature at which it is particularly susceptible to oxidation, while the moisture level is still excessively high. Extensive oxidation results. This situation can be corrected by assuring a low moisture content before the part reaches this temperature range.

Since the rapid-reaction temperature level of most metals is well above 600 F, the part may be safely held at this temperature until an acceptably low moisture level is attained. Figure 4 illustrates the application of this principle as one means of correcting the poor purging procedure shown in Fig. 3.

An additional means of facilitating the rapid attainment of an acceptably low contaminant level is demonstrated in Fig. 5. In this example the amount of porous refractory within the retort has been minimized. The period of relatively constant, high moisture level, typical of the slow outgassing of porous materials (Stage D in Figs. 3 and 4), has been greatly reduced. Whenever possible, troublesome outgassing substances such as porous materials, hydrates and organic binders should be eliminated or at least minimized. Those which must be used may occasionally be placed completely outside the actual gas system by modifying the physical setup. When this is not possible, any porous material used inside the retort should be thoroughly prepurged to remove contaminants and then continuously maintained in a high-purity atmosphere, preferably above 250 F, to minimize further contaminant pickup.

Figure 6 illustrates a further step in improving purging efficiency. In addition to minimizing the porous refractory as in Fig. 5, the ambient temperature purge has been eliminated. It can be seen that an acceptable moisture content is achieved more rapidly in this example with a resultant saving in purge gas consumption.

Figures 3, 4 and 5 illustrate that a large amount of contamination remained within the retort even after an ambient temperature purge. The reduction of this residual contamination to an acceptable level is accomplished by sufficient hot purging between 250 F and the rapid-reaction temperature of the metals involved. Because the part may safely be exposed to high contaminant levels at the relatively low temperature of the "hot" purge, there is seldom a

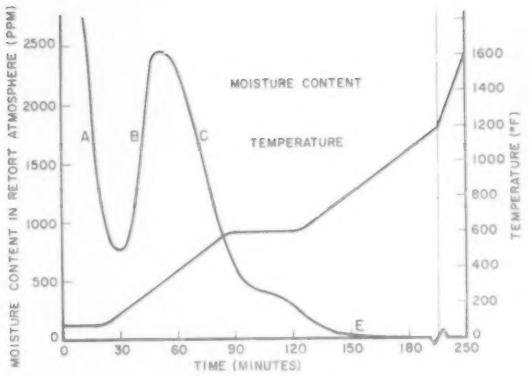


Fig. 5—Acceptable braze achieved more rapidly by modifying thermal cycle and physical setup

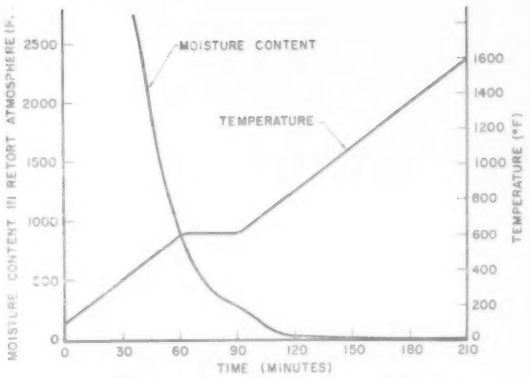


Fig. 6—Acceptable braze achieved most efficiently by modifying thermal cycle, physical setup and purge cycle

valid reason for retaining an ambient temperature purge.

It may be well to emphasize at this point that most of the contamination encountered during high-purity argon brazing originates within the brazing retort. Even a theoretically perfect gas purifier would be unable to substantially improve the high-purity of the gas entering the retort, and it cannot solve a contamination problem which originates within the retort.

Summary

High-purity argon atmospheres can provide the surface protection required for fluxless brazing of superalloys and other difficult-to-braze materials. It is essential that low contamination levels be achieved in the joint area. This is accomplished in two straightforward steps.

First, high-purity argon must be supplied to the brazing retort. The general principles involved in this step are outlined with particular emphasis on maintaining the as-delivered purity to the use-point. It is pointed out that the use of gas purifiers is normally unnecessary and even undesirable in accomplishing this step.

Second, the contamination originally contained in the retort must be removed. This difficult job may often be greatly facilitated by the application of displacement purging, hot purging, or a combination of both. It must be stressed that the contamination within the retort must be reduced to an acceptable level before the joint area reaches a temperature at which reaction with the contaminant becomes rapid.

IMPORTANT NOTICE

Over Labor Day weekend, all departments of the American Welding Society—including the Welding Journal—moved from 33 West 39th Street in New York City to new quarters in the United Engineering Center. Thus all future communications should be directed to the desired AWS department at:

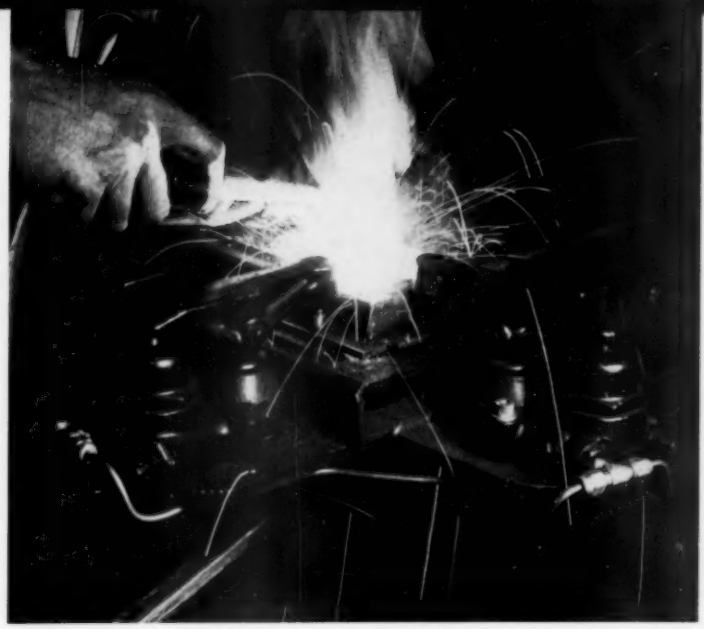
American Welding Society, Inc.
345 East 47th Street
New York 17, New York

Telephone: PLaza 2-6800

Economic Processing of **Weldments**

for IBM data processing machine frames involves the use of a new hydraulic swing clamp

BY GORDON A. MATTHEWS



Hydraulic swing clamp permits easy access to corners in welding of IBM machine frames

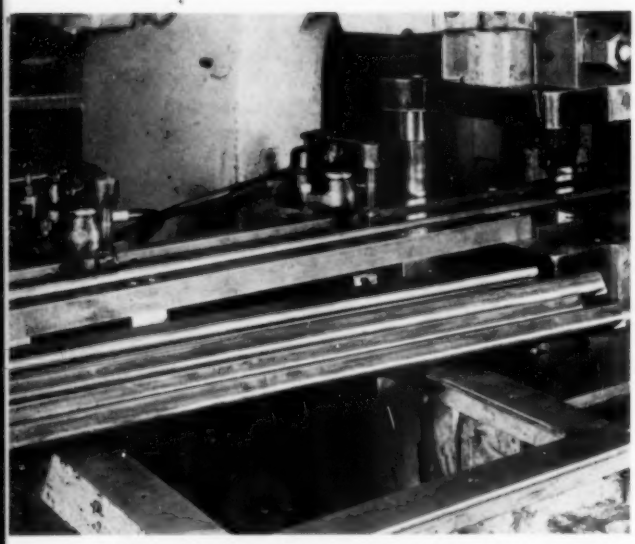
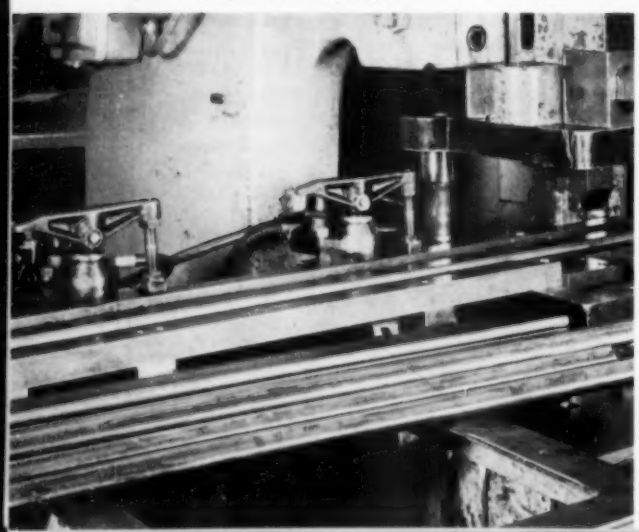


Fig. 1—Z bar being held in place with two hydraulic swing clamps

Fig. 2—Swing clamps in open position



Welding and its place in modern manufacturing are well established. The advantages of welding as used for example, in the fabrication of IBM data processing machine frames are numerous. The economic manufacture of these components and the maintenance of the welding's competitive position depends on the progressive application of developments in related fields. Thus a choice of gas metal-arc welding gets the processing of the IBM machine frames off to a good start. On the other hand, a roadblock to weldment engineering has been time-consuming and clumsy techniques of getting the parts ready for the welder with something like dispatch and efficiency. Actually welding has often been hamstrung with an ox-cart approach to holding the fabricated parts to required pattern and tolerance specifications.

Manually operated holding devices such as the C clamps have long since passed the retirement age. What is needed here was not merely the mechanically operated hydraulic, pneumatic or other clamping or an assembly device for weldments; instead need was for a device that with the flick of the wrist does its work unobtrusively, is out of the way, is easily and quickly readied for the job and—above all—that can be applied to a wide range of job specifications. Furthermore, it was necessary that such a device be adaptable for the fabrication of weldment parts as well as for both cutting Z-bars to length and notching them in addition to holding these units to pattern and tolerance specifications for the critical welding phase.

GORDON A. MATTHEWS is President, Mer-Lit Fabricating Corp., Johnson City, N. Y.

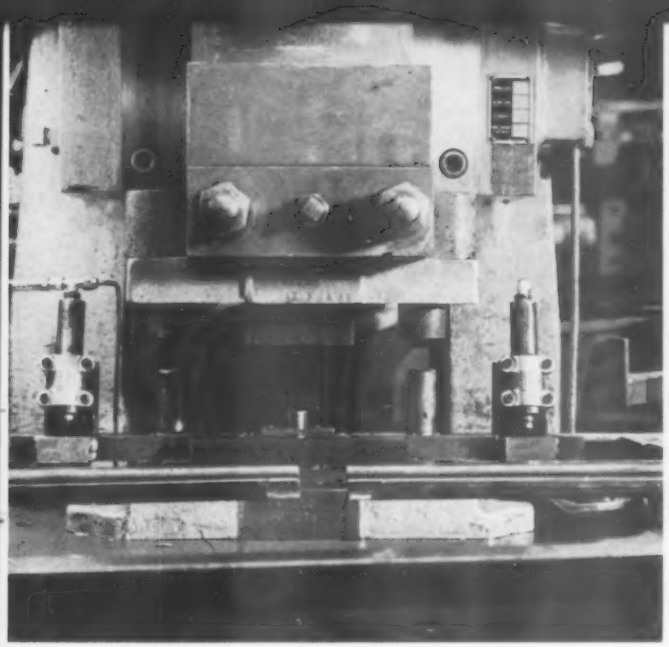


Fig. 3—Notched Z bars—clamps open

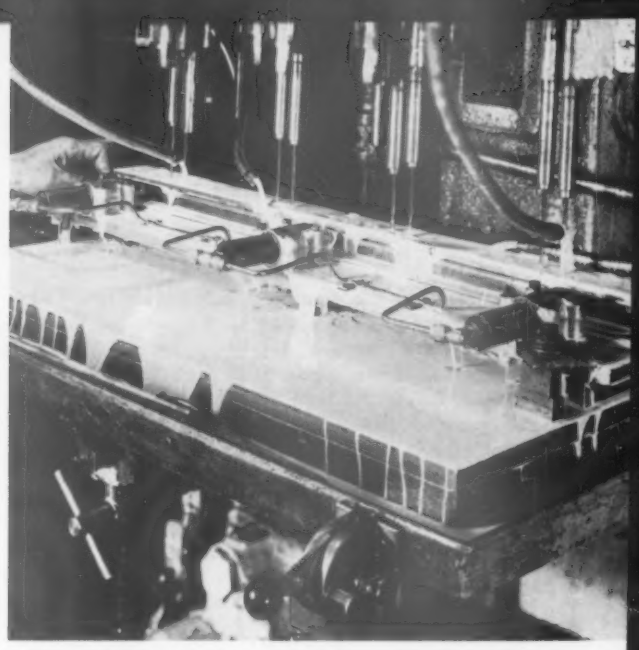


Fig. 4—Automatic drilling of Z bar

Hydraulic Swing Clamp

The approach to fabricating IBM machine frames began with specifying a new hydraulic swing clamp, by Newton Hydraulic Tooling Co., for bringing structural members in standard length to the press for parting—Fig. 1. As seen in Fig. 1, the Z-bar has been dropped into a channel fixture with a holding pressure of 900 lb at each point. As loaded ready for shearing or parting, the hydraulic clamps are of the traditional lever and fulcrum design. They are traditional, except for one important economy specification: the clamps are strictly out of the way when "at ease" as obvious from Fig. 2. However, the "payoff" comes only with decreased floor-to-floor time, and here careful costing figures indicated a saving of 18%—that is, the time for the piece in process for this operation of parting has been speeded up by this amount.

Notching or readying the structural bars for prewelding assembly follows through with the same specifications of the standard hydraulic swing clamp cylinder that can be assembled, applied and attached in an infinite variety of ways. Notched Z-bars are shown in Fig. 3 after operation completion. Handling or readying time is reduced for this phase so that the floor-to-floor time is lessened by 12%.

Weldments for the IBM machine frames are specified with drilled and tapped holes. The automatic drilling machine in Fig. 4 with the processed modified Z-bar, produces these parts with a 20% reduction in time, the manner in which the hydraulic clamps are located against the Z-bar at 240 lb per hydraulic clamp is shown in Fig. 5. With this arrangement, operator fatigue is reduced to a minimum through the ease of operating a plug type air valve. This aspect of modern manufacturing—operator well being—is important in these days of closely cropped time allotments necessary for competitive manufacture.

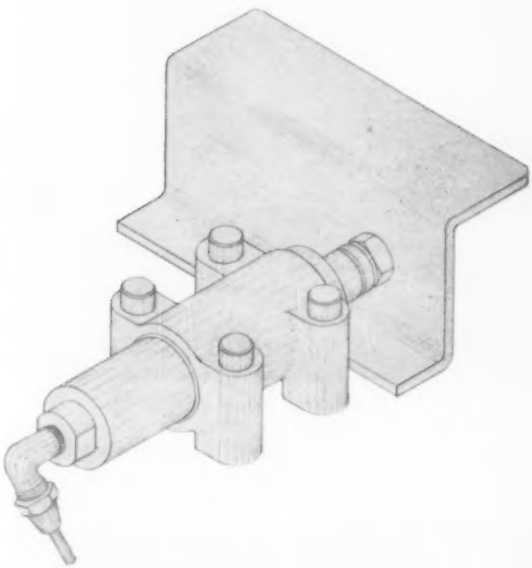


Fig. 5—Clamps loaded against modified Z bar

Clamp Versatility

Perhaps the most vivid illustration of the advantages associated with use of the hydraulic device with its swing clamping discussed here is presented in Fig. 6 where one side of the frame is ready for welding. At the operator's command once the structural members are in place, the clamps immediately act to hold the work rigidly and uniformly for good weldment processing. The ease of weldment removal once welding is completed is indicated in Fig. 7. To sum up, swing clamps make it easy for operators to load components into the base and top structure and make it just as easy to remove the

welded structure from the jig. Welding in corners of the frame with no protruding parts to get in the way of welders' hands is vividly shown in the lead photograph.

The box-like weldment frame is now ready for final assembly and welding. Here again simplicity of the hydraulic clamping operation strikes the observer. Four simple hydraulic cylinders (on top of frame) push down with 400 lb pressure against the base of the jig to hold the close toleranced data processing frames. Figures 8 and 9 pin point this stage of the operation and again emphasize the welder's consideration worked into these clamping applications. It is noteworthy these weldments are toleranced $\pm$ $^1/_{32}$ in. and the hydraulic units with swing clamping meet this specification.

The poetry of this operation is in the final cost figures: Tooling is amortized in six months against a five-year program; the 40% over-all production increase permits this.

Summary

As used in the fabrication of IBM, hydraulic swing clamps were shown to have certain key features which helped reduce operating costs. These are:

1. Clamping as well as de-clamping time is one second on all clamps.
2. Operator fatigue is reduced to a minimum, and the clamps meet high operator acceptance.
3. By eliminating unequal clamping pressure distortion, Newton hydraulic swing clamps help eliminate rejects which are inevitable with manually operated clamps.
4. The swing clamps are always where wanted and never in the way.

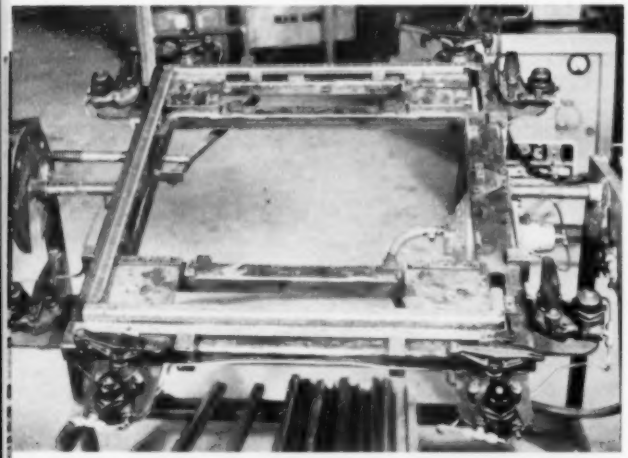


Fig. 6—Partially loaded swing clamps with one side ready for welding

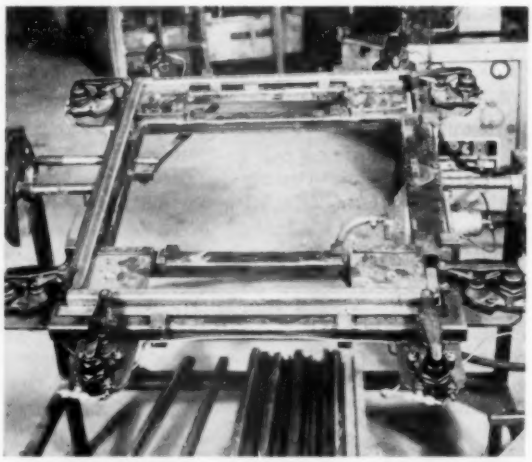


Fig. 7—Swing clamps closed with 450 lb pressure each to hold frame base in close tolerance location

Fig. 8—Push-type clamps closed with 400 lb pressure to locate close tolerances on pads for IBM machine frames

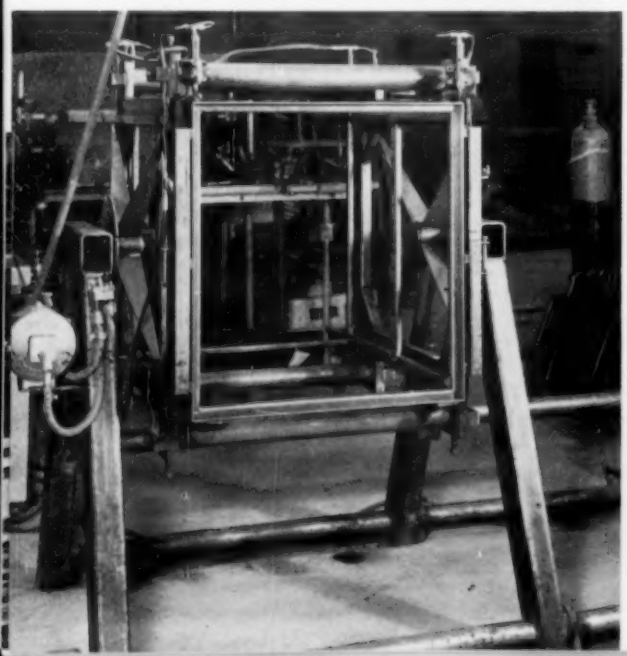
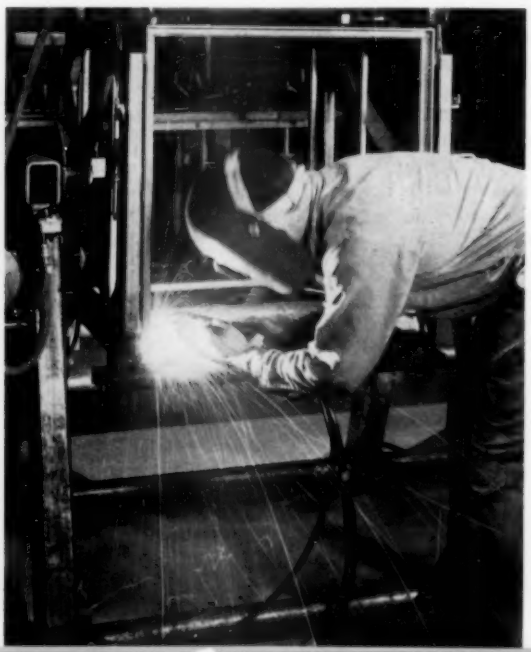


Fig. 9—Gas metal-arc welding showing application of push-type clamp on rotating welding fixture



A Practical Design Approach to Resistance **Weld Peeling** Loads

involves six peel-reducing techniques following an analysis of the causes of peeling after spot welding

BY W. P. KRAUS

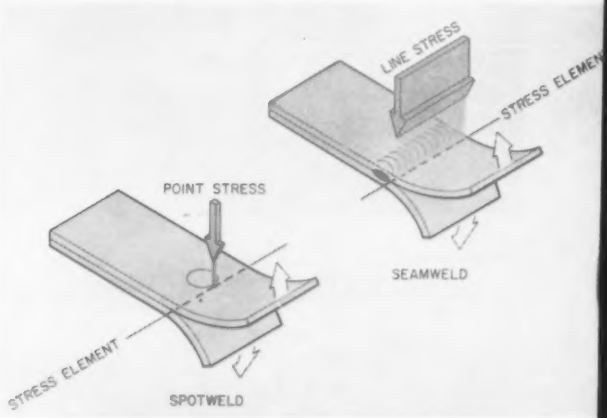
The trend of today's airborne structures is toward large thin-skinned pressure vessels. Manufacturers use high-tensile sheet materials, which develop the desirable hoop-tension properties, but are penalized because these thin skins buckle more readily. The structures are stabilized by stiffening with longerons, corrugations and frames. These can best be attached by spot welding. When skin flexing occurs due to pressure or body buckling, the spot welds are loaded in *tension* normal to the skin. This tends to tear them out.

Peeling

As illustrated in Fig. 1, any load normal to the skin produces a peeling effect. Notice that peeling on a spot weld results in a *point* of stress, while peeling on a seam weld results in a *line* of stress. The severity of this peeling action is dependent upon several factors which this paper tries to evaluate.

For many years, designers have been warned against loading spot welds in tension, even though this has long been used as a criterion of spot weld *quality*. For example, a tension value of 25% lap-shear spot weld strength is used as an indication of spot weld ductility in the MIL-Specification. Surprisingly enough, design manuals and specifications still do not recognize peel loading as a quantitative

Fig. 1—"Normal-tension" loading



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Paper presented at the ASM-AWS Technical Meeting, Western Metal Congress, held in Los Angeles, Calif., during March 1959.

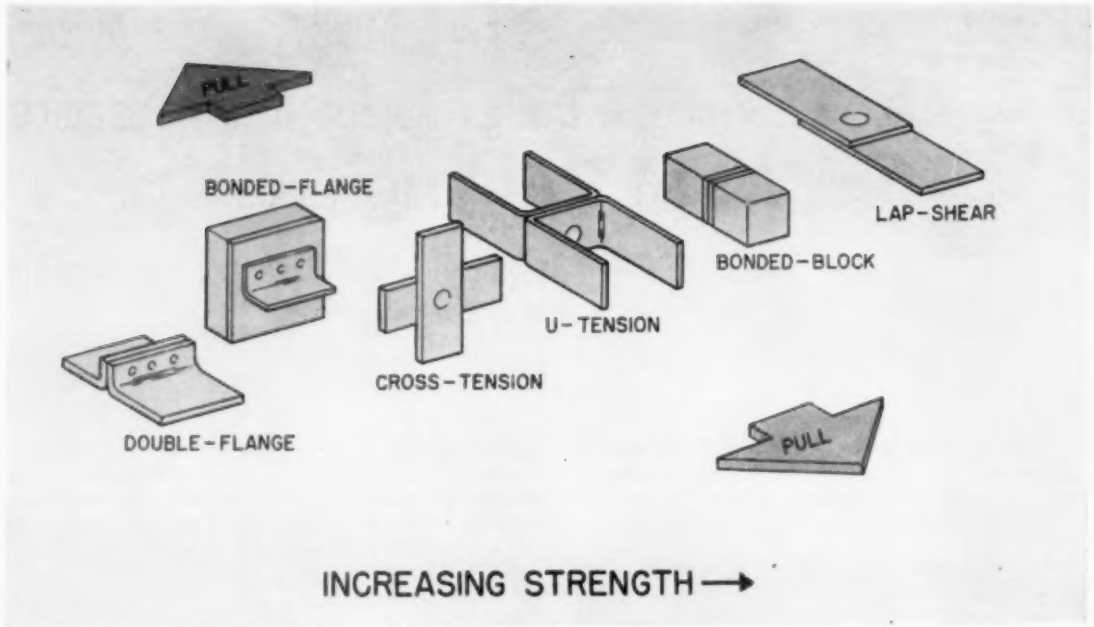
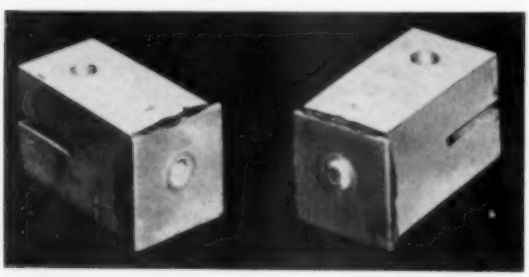
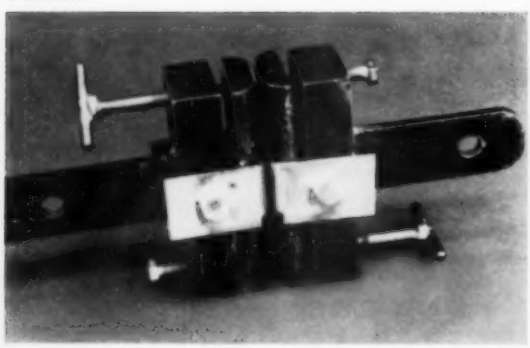


Fig. 2—Test specimens in order of increasing strength

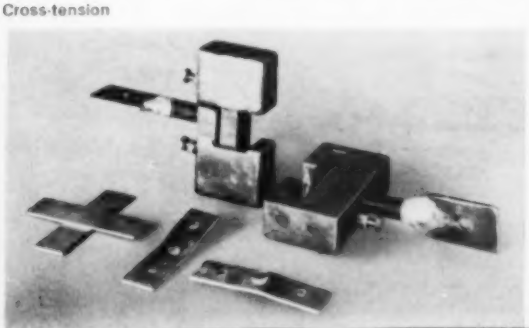
Fig. 3—Spot weld normal-tension specimens



U-tension



Cross-tension



variable, since most data are derived from one single arbitrary test configuration. But, since the new structures *do* load welds in tension, one cannot deny the existence of such peel loading. Test configurations similar to the cross-tension are usually used, but the problem is, "What do we do about designs which are *not* represented by this cross-tension test?"

Other tension tests utilize square or triangular tension specimens whereby the spot welds are pushed apart by pins, rather than pulled apart, in an effort to produce *pure* tension normal to the skin. The resulting higher numbers are as misleading as any other single test. Although interesting theoretically, it is not pure tension values which are sought for realistic design allowables. It is somewhat similar to using a metal for some unstated "high temperature" application without knowing the predicted temperature range: To be safe, the designer would have to apply characteristics derived from tests at the highest possible temperatures, rather than the practical anticipated temperature. A more realistic evaluation of normal-tension loading is in order, with assignment of appropriate strengths to various joint configurations. So, a theory was developed that spot welds in peel will exhibit predictable strengths of a considerable range. This wide spectrum of ultimate loads is reproducible by a family of curves which can be utilized, as are temperatures curves, to provide realistic design allowables data for *each* applied joint configuration.

Checks on Theory

Two steps were proposed to check this theory: The first was to test a wide variety of spot welded

joints and plot their peeling characteristics to develop the strength spectra. This procedure is intended to provide design data. The second, was utilization of *one* of these test joints for comparative purposes. The standard cross-tension test was retained for this purpose. This *single* test is useful for machine schedule development, weld quality, post-weld heat treating and material weldability comparisons.

The series of test configurations finally selected is shown in Fig. 2. They have been plotted in their order of increasing peel resistance. For comparison, the standard lap-shear specimen is at the extreme upper right.

At the lower left of Fig. 2 is the worst condition of peel loading which, fortunately, rarely exists in structures. As peel resistance increases to the right, one finally obtains the bonded-block tension configuration. Notice the position on the chart relative to peel severity of three of these tests: the bonded-block, U-tension, and cross-tension; these are shown in more detail in Fig. 3.

The bonded-block specimen in Fig. 3 represents as close an approach to *pure normal tension* loading as it was possible to get. The ultimate loads achieved with 2024 aluminum specimens agreed very closely with the calculated peripheral shear strength of the parent metal heat affected zone, around the weld nugget. Unfortunately, with thicker aluminum as well as the other metals, the epoxy resin interface bond failed.

The U-tension test results in a symmetrical 2-point loading on the spot weld. The adjustments on the test fixture allow the weld to be pulled with a controlled amount of deflection. The cross-tension specimen is held in the test fixture with 1-in. unsupported spans at the spot weld. This loads the spot symmetrically at 4 points. It results in a somewhat more peel-sensitive joint.

Test Results

Referring to Fig. 4, the first tests were run with 2024-T3 aluminum alloy and results of the various configurations were plotted. The strongest welds were those of the standard lap-shear specimen shown here for comparison. As may be expected, the weakest joint was the double flange specimen which consisted of two flanges spot welded together, giving the most stringent peel conditions and which represented the lowest level of weld strength. Between these two are plotted the strengths of the other specimens. It will be noticed that the bonded-block tension specimen was only tested up through approximately 0.055 in. thickness. It does show good correlation and falls in the theoretical range of tension strengths.

In Fig. 5 are the same types of tests on 17 – 7PH spot welds. It was not possible to get a bonded-block tension specimen to stick, but it was known that it would fit in somewhere between the U-tension and the lap-shear curves. At the upper portion of

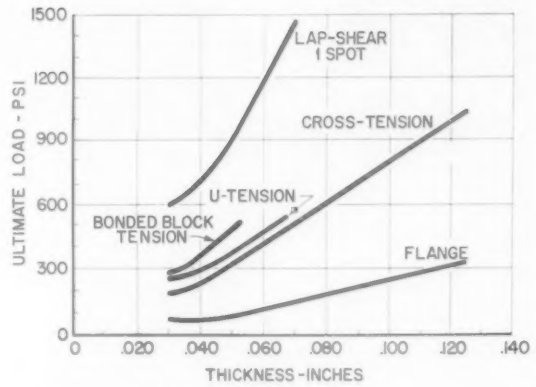


Fig. 4—2024-T3 aluminum alloy spot welds in tension and shear loading

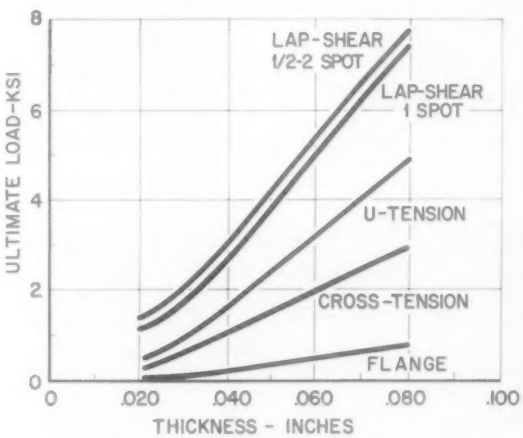


Fig. 5—17-7PH spot welds in tension and shear loading

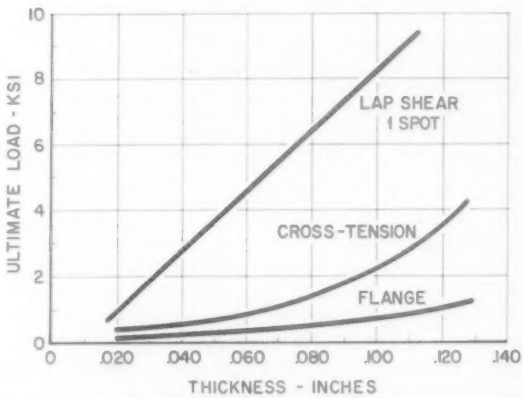


Fig. 6—RCA-110AT titanium alloy spot welds in tension and shear loading

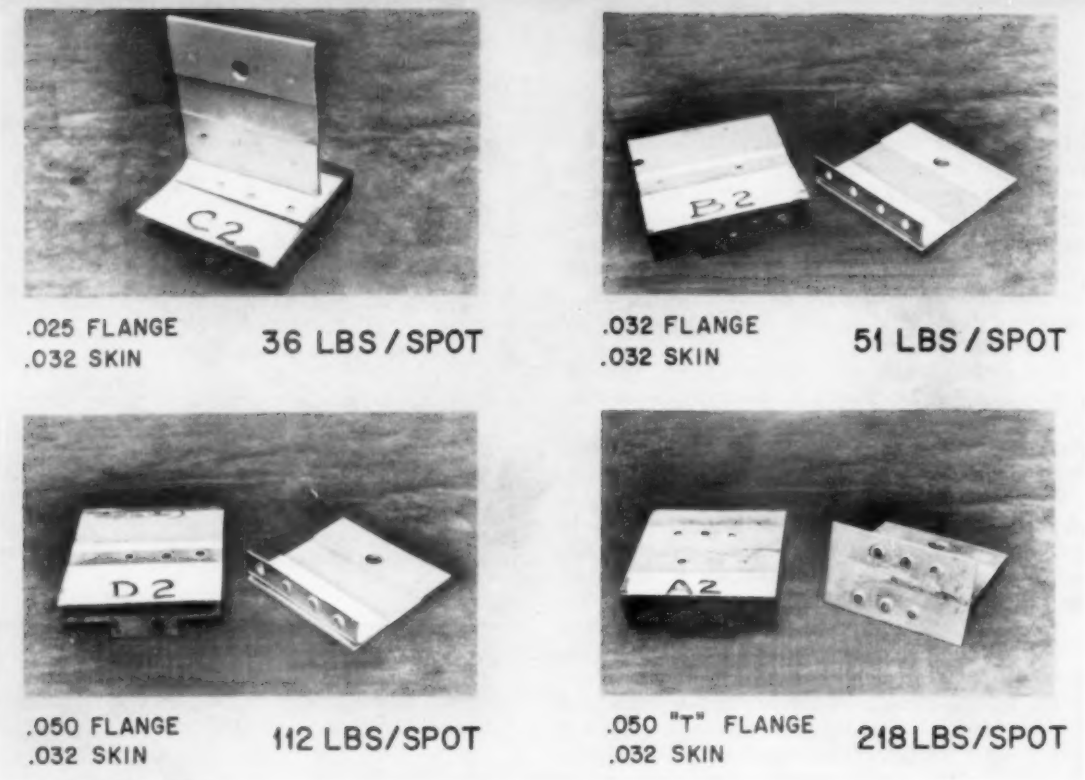


Fig. 7—How flange variables affect spot weld peeling loads

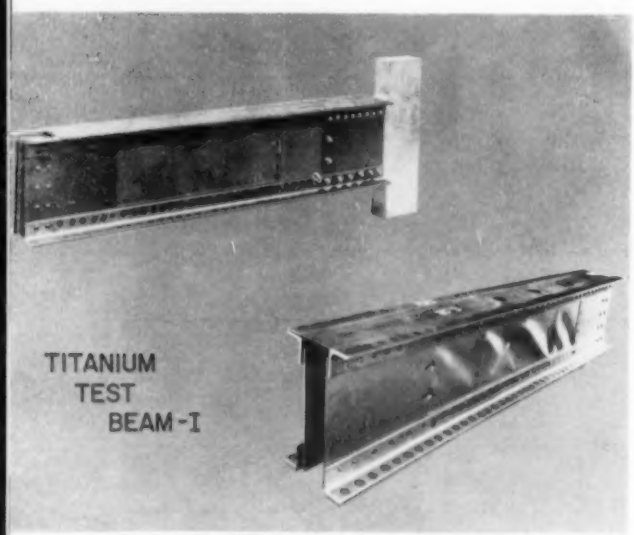


Fig. 8—Titanium test beam—I

the plot, two lines represent lap-shear. The upper of the two consisted of two tandem spots and the plotted strength is one-half of this double spot joint. There is a difference between this one and the single spot, because the two spots in shear stabilized the specimen so that peeling was minimized.

Figure 6 shows the results of the same test configurations with the aluminum-tin titanium alloy. The curves show the decided peel sensitivity of the titanium alloys and, as a result, the designer will have to use every "trick in the book" to be able to utilize titanium alloys under peeling loads.

Minimization of Peeling

Figure 7 shows four spot welded flange specimens in 2024-T3 aluminum alloy. This configuration is similar to a skin attached by flanges, where the loads are normal to the skin. After spot welding the specimens, the "skins" were bonded to the steel support blocks with epoxy resin. The thickness of these simulated skins in each case was 0.032 in.

The specimen at the upper left with an 0.025-in. thick flange pulled an ultimate load of 36 lb per spot. The flange of the specimen at the upper right was increased in thickness to 0.032 in., and the ultimate load went up to 51 lb per spot.

The flange of the specimen at the lower left of Fig. 7 was increased to 0.050 in. (still against the 0.032-in. skin), and the ultimate load went to 112 lb per spot. The specimen at the lower right had an 0.050 in. extruded T-flange. The ultimate load of this test was 218 lb per spot.

It should be noted that all four specimens were "tension-peel," yet their peel resistance varied significantly. Their ultimate loads depended upon *variables* of flange thickness and stiffness, rather than only the thickness of the thinner sheet. Examination of these four test pieces showed that as the flanges were stiffened, the spots were loaded more uniformly in normal tension and less in peel. Each

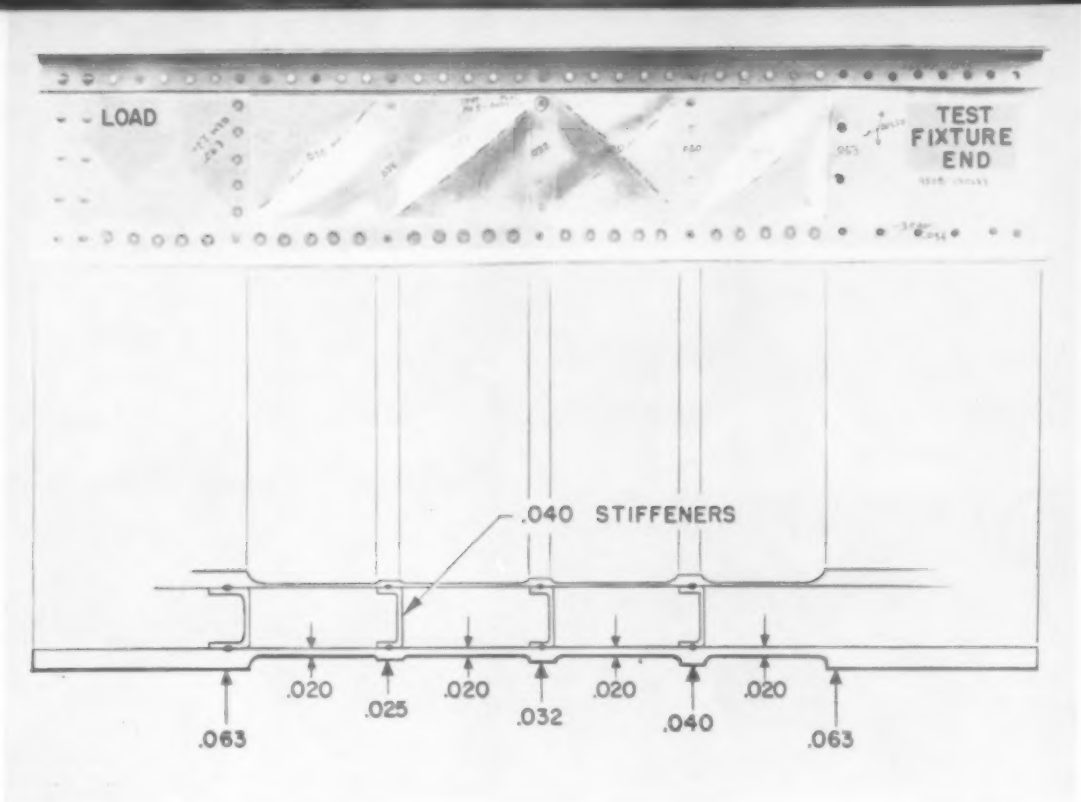


Fig. 9—Titanium test beam—II

spot was loaded circumferentially instead of at the stress element tangent along the heel of the flange. Even though all of these specimens are considered "tension" specimens, one *single* design allowable value cannot apply to all of them.

Figure 8 illustrates an interesting test which illustrated several things about spot welds in tension. This structure consisted of a tension field web box beam. The material was titanium, aluminum-tin alloy. One end of the beam was cantilevered out from the fixture and loaded downward. Now, in a tension-web beam, the thin webs will buckle elastically under load. The buckling tends to pull out the stiffener fastenings—in this case, spot welds. It was known that spot welds in titanium alloys were very sensitive to peeling failure as seen previously. Thus it was predicted that, due to buckling, the spot welds would pull out at a much lower stress level than the web strength afforded. The webs were reduced locally, to 0.020 in. by the Chem-Mill process, leaving lands across the webs for stiffener attachment reinforcement.

Based upon existing spot weld strength data, the beam's ultimate flexural strength was expected to be 7500 lb. After applying this load of 7500 lb and observing only *elastic* web buckling, no *plastic* deformation or weld failure was found. The beam was again loaded—this time progressively. At 15,500 lb, 5 spots failed due to the peeling stress of web buckling. The diagonal plastic deformation after failure is clearly seen in Fig. 9 and indicates that:

1. A web's ultimate tensile strength can be utilized by increasing the weld peel strength; this is a good weight saver.

2. Spot welds in peel-sensitive material can be forced to carry increased loads by designing a more peel-resistant structure.

Recommended Techniques

Some techniques which can be used to get stronger and more peel-resistant structures are shown in Fig. 10:

1. The first joint, a flange attached to a skin, is loaded so that the skin tends to pull off and peel the spot welds. The simplest improvement is to increase the number of spot welds on the flange; this reduces the unit loading of each spot weld.

2. For structures requiring the highest resistance to peeling, consideration should be given to the use of *seam welds* rather than individual spot welds. In tests, seam welds always showed a much higher resistance to peel than any row or pattern of individual spot welds. One word of caution on seam welds is, advisable, however.

Because of the annealed heat-affected zone adjacent to the weld, some joint efficiency is lost. In many cases, this ultimate tensile factor is *not* as critical as peel resistance; it is for those cases that the use of seam welds will be advantageous.

3. The next technique is to increase joint thickness locally, at the point of attachment as was done on

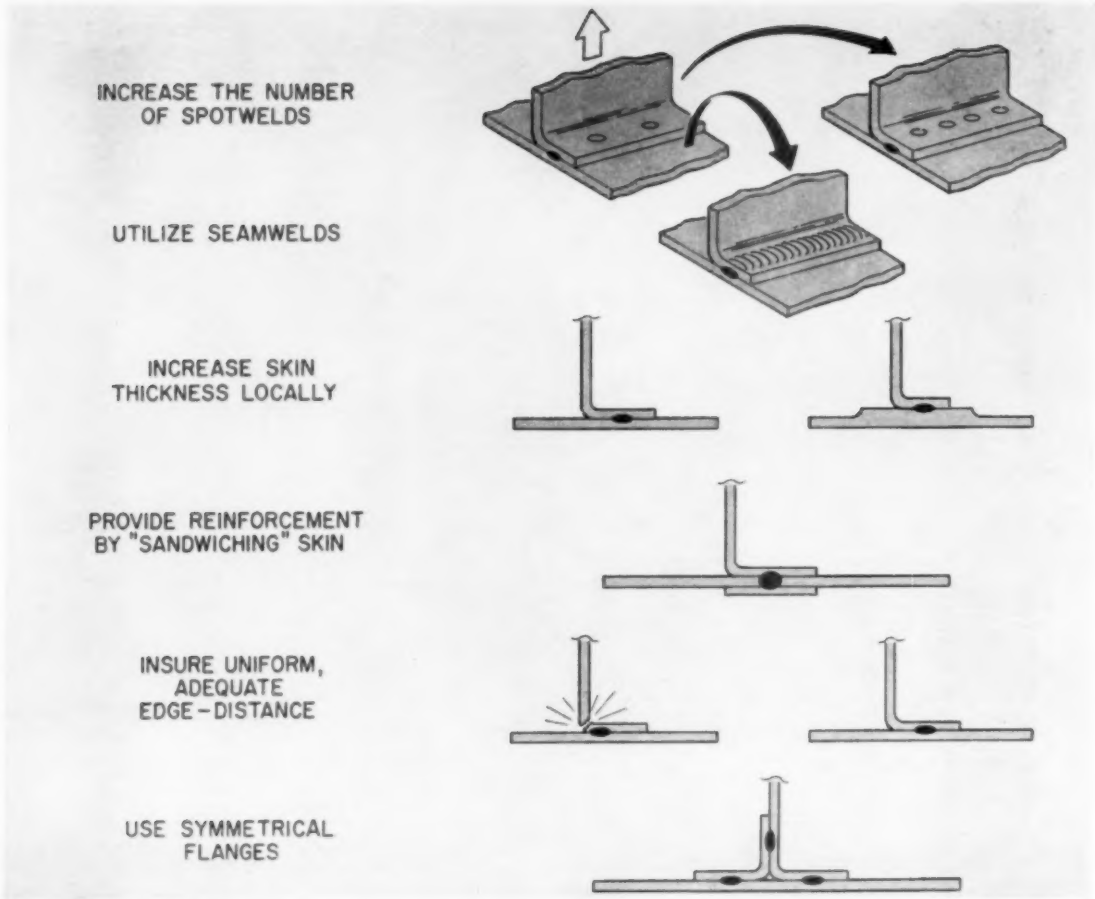


Fig. 10—Peel reducing techniques

the titanium beam test. In this case, the web areas had been reduced by Chem-Milling, leaving thicker lands for attaching stiffeners. The thicker land not only provides a stronger spot weld but also acts as a stiffener to resist local skin buckling with resultant peeling.

In the case of a pressure vessel where leaks cannot be tolerated, increasing the land thickness insures that, if any failure occurs, it will be by selectively pulling a slug out of the flange internally rather than from the tank skin itself.

4. The next example shows how peel resistance can be increased by providing additional reinforcement on the opposite side of the attaching member and thus sandwiching the skin. This is a simple and economical method where an aerodynamic surface is not needed, such as an internal joint, or a bulkhead.

5. The next concerns itself more with shop technique and quality control. The example on the left shows a spot weld inadvertently placed close to the heel of a thin attaching flange. Any stressing normal to the skin results in an immediate, high, local point of stress. The improved example on the right shows the spot weld placed in the center of the flange. Normal springing action will take place before peeling the edge of the spot weld. Consider one spot weld at the heel of a flange because of misalignment in a row of spots. Failure of the row could be precipitated by this one misplaced weld.

6. The last technique is the use of symmetrical flanges rather than single-leg flanges. This not only reduces the *unit* stress on each spot weld but distributes the load uniformly on the *row* of spot welds to reduce peeling. With symmetrical flanges, a closer approach to pure normal tension is achieved.

Summary

"Tension" is not descriptive of all the variables affecting joints under tension loading. A *single* configuration tension specimen should not be used for developing design allowables data; a range or a family of peel conditions exists for each material. Thus if a designer has available the full range of strengths and can then select the one *most appropriate* to his joint, he will design simpler, lighter and more reliable structures.

There *are* various techniques to locally strengthen spot welds so that their performance in peel *can* be optimized. The future trend will be to tie-in more actual flange and attachment-joint configurations into families of curves and from these curves, designers can pick out the anticipated tension loads.

Practical Welder and Designer

Gas Welding Goes Collegiate

The Pi Kappa Alpha fraternity house at the University of Denver is likely to be the envy of many other fraternities. Striking in its appearance, it also is practical in its provisions for comfort.

The chapter house boasts of Denver's first "Geodesic dome," a spherical section, 70 ft in diameter, covering a five-sided, glass-walled building in which the recreation and chapter rooms are located. This is linked by an enclosed passageway to a two-story dormitory building, 82.2 by 33 ft.

The architect used radiant heating throughout the fraternity house. In the dormitory building, heat is circulated through the baseboard area, but in the recreation building the radiant heating pipes are arranged as a grid in the floor. The exterior walls of the recreation building are largely of $^3/_{16}$-in. crystal sheet glass, which allows greater heat loss than a solid wall. Because of this, and the fact that the Geodesic dome has no interior supports, it was felt that heating from the floor was essential here.

The boiler room is located on the lower level of the dormitory building. Nearly 4000 ft of Spang steel pipe is used to circulate the hot water to heat the two buildings. In the floor grid, the outer periphery consists of 1-in. pipe on 6-in. centers, leading to an intermediate zone of $^3/_4$-in. pipe on 11-in. centers, and an inner zone of $^3/_4$-in. pipe on 12-in. centers. Supply lines are of $1^1/_4$-in. pipe.

The entire piping job for the grid heating system was completed by two men in less than 60 hr. This included making many 30, 60 and 90 deg. bends, using a hydraulic pipe bender on cold pipe, and the welding of approximately half of the pipe. Once the piping installation was completed, a 100 psi internal pressure was applied for a 24-hr period; no leaks whatsoever were found.

Based on a story from National Supply Div., Armco Steel Corp., Pittsburgh, Pa.

Fig. 1—Welding a joint between two sizes of Spang steel pipe during installation of the radiant heating floor grid at the Pi Kappa Alpha fraternity house, University of Denver. Despite the need for considerable gas welding, and making many 30, 60 and 90 deg bends, two workmen installed nearly 4000 ft of pipe for the radiant heating system in less than 60 hr

Fig. 2—Complexity of radiant heating pipe installation. Outer periphery consists of 1-in. pipe on 6-in. centers. It leads to an intermediate zone of $^3/_4$-in. pipe on 11-in. centers, and an inner zone of $^3/_4$-in. pipe on 12-in. centers. The coils rest in pea gravel, above a 2-in. concrete slab covered with a vapor barrier. Later a 3-in. concrete floor slab was poured over the coil area

Fig. 1—View from the rear of the 6300-seat stadium addition, indicating how the three tiers of shop-welded deck sections were set in position on the structural framework below them

Stadium Addition has Stepped Deck Plates Assembled by Mechanized Welding

BY RUSSELL ASCHINGER

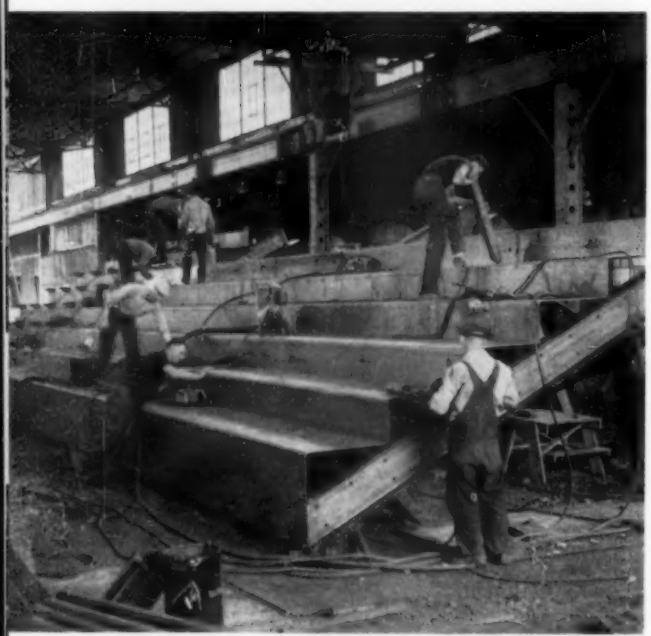


Fig. 2—Lower tier sections being shop welded. Operators in foreground are assembling seat plank clips and stairway boxes, while in center a mechanized welding unit runs the fillet on a tread-riser joint

Welding formed steel tread and riser plates into a 25-row deck for a stadium addition on the east side of the field at Vanderbilt University, Nashville, Tenn., proved to be a speedy, economical and efficient way to build the second enlargement to the home of the Vanderbilt Commodores. The first, on the west side, was made 12 years ago at considerably more time and expense.

The latest addition, recently completed, is in the shape of an arc about 400 ft long and on a 523 ft radius to conform with the shape of the field. It comprises 21 sections, each with three tiers of shop fabricated and welded plates. It measures 57 ft front to back and rises 30 ft at the rear above the level of the first row.

By the adaptation of a self-propelled tractor mounting an ML-3 "Squirt" welding gun, the Nashville Bridge Co. was able to lay down $^{1}/_{4}$-in. fillets along the tread and riser joints in the deck at a speed of 42 ipm, with current of 575 amp and 38 arc volts. The individual $^{3}/_{16}$-in. plates were brake formed with a 1 ft 1 in. riser and 2 ft 2 in. tread, bent with a $^{1}/_{2}$-in. radius at the corner and with the tread sloping upward $^{3}/_{4}$ in. from the flat for suitable drainage when installed.

Each of the 63 sections fabricated in the shop, some of them reinforced with $^{3}/_{16}$ in. backing strips intermittently welded behind the risers and under the treads, was completed and painted before shipment to the erection site. Two coats of black

RUSSELL ASCHINGER is Field Engineer, The Lincoln Electric Co., Nashville, Tenn.

bituminous paint were applied to the undersides and one to the topside, with paint stopped off 2 in. either side of any joint to be field welded. After assembly of the tier sections to each other and to the supporting structure, largely by manual welding, a coat of bituminous paint was applied and sprinkled with sand before drying, to give a nonskid surface. The bituminous paint coating also served as a sound-deadening layer to minimize any drumming effects from a stamping of feet or organized cheering.

The supporting framework structure consisted of WF columns, longitudinals and diagonals. Stadium curvature necessitated the tapering of each of the 21 three-tier deck sections by about 7 in. from top to bottom, so that when spliced they would form the desired arc. This was accomplished by suitable detailing and shop cutting of each plate.

The welded deck steps, supported on 12 in. channels, in turn carries on vertical columns and diagonal struts. The individual framing panels are further tied together by crosswise bracing angles on every fourth panel point.

At intervals along the deck, stairways are provided by welding on 39 in. wide boxed riser and tread elements with $^1/_2$ the height of the riser and $^1/_2$ the width of the tread. This gives a uniform $6^1/_2$ in. high step. The treads are rolled with a checkered diamond pattern for firm footing, while the deck plates at the stair positions have a matching Nabrico weld pattern, comprising rows of closely spaced buttons welded symmetrically.

Seat planks are bolted to T-section clips and manually welded to the forward edge of the deck treads about 4 ft apart. They are $8^1/_2$ in. long and $3^1/_2$ in. deep, with three holes drilled in each of the flanges for attaching the planks.

The job accounted for over 10,000 lineal feet of automatic submerged-arc and manual welding. Most of it was done in the shop with the tractor-mounted welding guns.

Fig. 3—Compact self-propelled tractor, mounting a mechanized welding gun set at 45 deg angle, makes the $^1/_4$-in. fillet joining riser to the tread below it. Submerged-arc unit operates at travel speed of 42 ipm

Welding Speeds Strip Mill Construction

Abounding in significant structural and functional advances, a new 80-in. hot strip mill in River Rouge, Mich., will become operational this year as the fastest and most automated rolling mill in the world. Expected to be the most accurate rolling mill in the world, the new facility will incorporate the latest advances in automatic controls. Structurally, designers and contractors are making the best possible uses of the latest methods in construction processes with emphasis on in-the-shop welding and high-tensile bolts in preference to conventional riveting. The mill buildings have more welded girders than projects of comparable size. The result: impressive economies in time and cost.

One major assignment of the prime contractor was fabrication of 17,200 ft of runway girders capable of supporting fast moving cranes of varying capacities up to 125 tons. The larger runway girders are 88 in. deep for the 48 ft spans and 102 in. deep for the 64 ft spans. One 96 ft span required a girder of 126 in. Size of the speedy cranes vary from 15 to 125 tons, used in four of the aisles, the latter having a maxi-

Based on story from Great Lakes Steel Corp., Detroit, Mich.

New 80-in. hot strip "mill of the future" is nearing completion on the banks of the Detroit River in River Rouge, Mich. Modern steel construction methods were used to cut erection costs and save time without sacrificing strength in the structure, which has roof expanse of 20 acres

mum wheel load of 145,000 lb (without impact) and a speed of 300 ft per min.

In fabricating these girders, the contractor utilized a submerged-arc welding unit, first of its kind employed in a structural fabricating plant and a massive machine capable of making one continuous $^5/_8$ in. fillet weld deposit in a single pass.

Mounted on rails, the welding machine served two beds of girders set at a 45-deg angle on either side of the fully automatic welding unit. With the electrode arm adjusted for the specific welds required, it produced a continuous $^5/_8$ in. fillet weld on each web-flange plate joint, completing two girders in eight passes. The first girder was welded on the up run while its mate was being lifted from its bed, swung around the reset for the return pass. The result was continuity of production with maximum use of welding. Only hand welding in the in-shop girder fabrication phase was affixing of web stiffeners.

Aside from the strength advantages of welding over riveting, this approach saved untold man hours of labor by eliminating such costly processes as riveting flange holes for angles and web-plates, as well as the need for punching and reaming.

Welding was also used exclusively for all jack trusses and building columns. The jack trusses run alongside the crane girders and are designed to carry the intermediate columns used to support the roof trusses, when they occur, and to provide a stiffening companion structure for the long crane girders. Not a single hole was punched or drilled in the main shaft of the main building columns.

Riveting Machine Combines Welded Frame and Steel Castings

BY JOHN HANNA

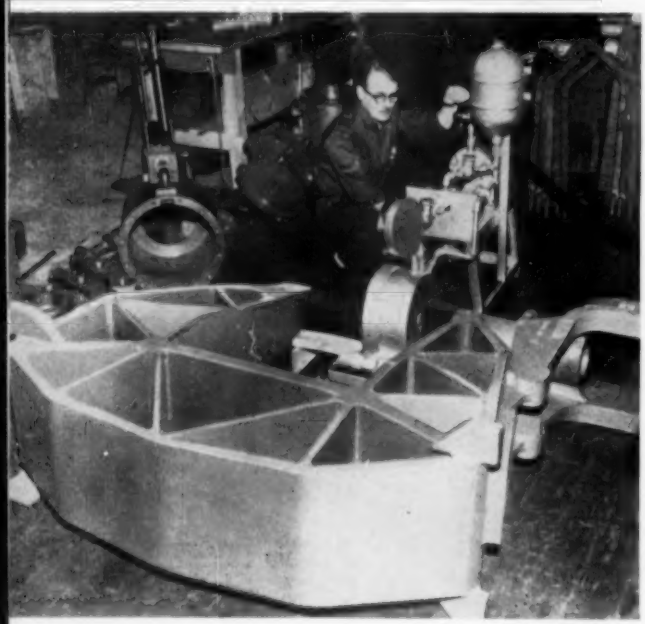


Fig. 1—Welded frame and casting combination for riveting machine

JOHN HANNA is President, Hanna Engineering Works, Chicago, Ill.

For fifty-eight years Hanna Engineering Works, Chicago, Ill., has been building the large squeeze-type multi-ton riveting machines which have been used in constructing many large bridges, buildings and oil cracking units over all the United States and other countries around the globe. These are big yoke riveting machines with working pressures of 30 to 175 tons and more. They have, up to now, been made of heavy steel castings in order to get the strength needed for this type of construction work.

After considerable effort, the Hanna engineers now have worked out a design of an 80-ton yoke riveter that is made up of a fabricated welded steel frame and two alloy steel castings for the nose and head parts. This new weldment-casting design takes full advantage of advanced welding techniques and also uses steel castings with differential heat treatment where they can best be used to achieve desired characteristics.

Design-wise, the frame structure of the new weldment-casting is engineered on the old concept of sticks and strings, the sticks being those elements which tend to get shorter and the strings being those parts which tend to get longer when under working strain. This new weldment-casting design has important advantages over a large riveting machine made of a single large steel casting.

Here are some of the advantages of using a fabricated weldment in making this structure as compared to a large casting:

1. By eliminating the need of large bulky patterns for sand castings. These are expensive to build, store, maintain and insure.
2. The two castings for the head and nose parts may be fitted to various sizes of fabricated welded riveter frames—an important flexibility in design advantage.
3. The nose part casting, which is under considerable strain on the riveter, can be heat treated separately to achieve a hardness which is impossible to attain when the structure is made of a single casting.

AMERICAN WELDING SOCIETY
INCORPORATED

345 EAST 47TH STREET • NEW YORK 17, NEW YORK

A NON-PROFIT ORGANIZATION FOUNDED IN 1919 FOR ADVANCING THE SCIENCE AND THE ART OF WELDING

FRED L. PLUMMER
NATIONAL SECRETARY

PLAZA 2-6800

October 1, 1961

AN INVITATION TO AUTHORS

—to participate in the American Welding Society's

1962 AWS National Fall Meeting

Milwaukee, Wisc., October 1–4

Gentlemen:

The American Welding Society will hold its 1962 National Fall Meeting and Exposition in Milwaukee, Wisc., October 1–4, 1962.

Each year our Society offers opportunities to Authors for bringing their outstanding work, development and research to the attention of our Membership and the welding and metals industry, by having previously unpresented and unpublished papers presented at its national meetings.

The Society's Technical Papers Committee will be happy to receive your application for entry in the 1962 National Fall Meeting activity. All applications, abstracts and manuscripts will be screened by the Committee, and Authors will be notified sometime in March 1962 regarding acceptance.

Each abstract should be sufficiently descriptive to give the Committee a clear idea of the content of the proposed paper. In any case, it must contain *not less than 500—but preferably not more than 1000—words.* Also, in order to place the Committee in the best possible position to evaluate these papers, it is suggested that each abstract be accompanied by a complete manuscript.

The Committee reserves the right to consider all applications on the basis of acceptance for placing on the 1962 National Fall Meeting program, or consideration for placing on the 44th Annual Meeting program, the next national meeting of the Society. Papers may be considered for publication in the *Welding Journal* regardless of acceptance for presentation at either Meeting.

Papers dealing with latest developments in (1) design and fabrication of all types of weldments, including machinery, (2) welding of aircrafts and rockets, (3) fabrication and maintenance of equipment used for radioactive applications, (4) pressure vessels and storage tanks, (5) equipment and pipe lines used in petroleum industry, (6) structures, (7) automation as applied to welding processes, (8) resistance spot, seam and projection welding, (9) gas-shielded arc welding, (10) new processes, (11) welding of castings and composite structures, (12) welding of "new" alloys, (13) weldability of high-strength steels, (14) welding of aluminum, magnesium, zirconium, titanium, molybdenum and like metals, (15) brazing, (16) maintenance, (17) surfacing, (18) soft soldering, (19) adhesive bonding, (20) welding of plastics, and (21) practical applications or "how-to-do" topics are deemed to be of particular interest at the Milwaukee meeting. However, any papers dealing with the educational and informative categories of welding production, engineering, research and metallurgy, are welcomed as long as the subject falls within the field of our Society's activities.

Please fill out the Author's Application Form on reverse side of this letter, attach abstract thereto, and return to AWS. To assure consideration for the 1962 National Fall Meeting program, your abstract must reach AWS not later than January 15, 1962.

Sincerely,

Fred L. Plummer

Fred L. Plummer
National Secretary

IMPORTANT: ABSTRACTS CONTAINING LESS THAN 500 WORDS AND THOSE POSTMARKED LATER THAN JANUARY 15, 1962, WILL NOT BE CONSIDERED.

AUTHOR'S APPLICATION FORM
FOR
1962 AWS NATIONAL FALL MEETING
OCTOBER 1-4, 1962

DEADLINE
JANUARY 15
1962

Complete in Full and Return to American Welding Society, Inc., 345 East 47th Street, New York 17, N.Y.

Date Mailed .....

Author's Name .....

Company or Organization .....

Title or Position .....

Mailing Address ..... City ..... State .....

If there are to be Joint Authorships, give name(s) of other author(s)

Name .....
Address .....
Name .....
Address .....

PROPOSED TITLE (10 words or less): _____

SUBJECT CLASSIFICATION:

- Classify your paper by placing check mark in appropriate box:
  Industrial Application ☐ Engineering or Design Data ☐ Process Development ☐ Shop Practice ☐
  Original Research ☐ Education ☐ Other ☐ _____ (state which)

ABSTRACT:

- Type, single spaced, an abstract of *not less than 500—but preferably not more than 1000—words* on separate sheet and attach to this form. Be sure to give sufficient information to enable Technical Papers Committee to obtain a clear idea of content of proposed paper.
- If complete manuscript is available, in addition to abstract, please attach copy hereto.
- Application Form and Abstract *must* reach AWS Headquarters not later than January 15, 1962, to assure consideration for 1962 National Fall Meeting.

MANUSCRIPT DEADLINES:

- All manuscripts *must* be in the hands of the Technical Papers Committee not later than July 15, 1962. If received prior to May 15, 1962, every effort will be made to publish them in advance of meeting.
- It is expected that the Committee's selections will be announced sometime in March, 1962.
- If your paper is made a part of the program, which of the following manuscript deadlines will you be able to meet?
  May 15, 1962 ☐ June 15, 1962 ☐ July 15, 1962 ☐
- If manuscript is attached hereto, please check here ☐

PRESENTATION AND PUBLICATION OF PAPERS:

- Has material in this paper been previously presented in meeting or published?
  Yes ☐ No ☐ When? _____ Where? _____
- Following presentation at the Society's 1962 National Fall Meeting, would you accept invitation to present this paper before AWS Sections? Yes ☐ No ☐
- Papers accepted for presentation become the property of the Society, with original publication rights assigned to the *Welding Journal*.

RETURN TO AWS HEADQUARTERS. MUST BE RECEIVED **NOT LATER THAN JANUARY 15, 1962,** *TO ASSURE CONSIDERATION.*
ABSTRACT MUST CONTAIN NOT LESS THAN 500 WORDS.

_____
Author's Signature

4. Delivery is improved considerably in that the welded structure can be fabricated on a custom order basis in a matter of about four weeks, whereas a large casting of this size has to be scheduled in such a manner that it often takes two or three months to get one.

5. The cost of manufacturing is also less with the weldment-casting type of construction.

The 2250-lb frame structure is made of hot rolled steel plate stock 16 in. wide, and $^3/_4$, $1^1/_2$, $1^3/_4$ in. thick, with 4 x 4 in. bars for intersection blocks.

All welding was electric arc, positioned for gravity flow, using E-7018 low-hydrogen iron-powder electrodes for the first pass root welds, followed by scarf welds with E-6020 electrodes. All welds were made with 100% penetration so that all welds equal or exceed plate section areas. E-7024 electrodes were used for all fillet welds.

The two castings and the frame areas onto which the castings were to be welded were pre-heated before welding with E-6020 electrodes. The 925-lb head casting was made of 28–32 point carbon steel. The 225-lb nose casting was made of Falk Moly telastic steel, differentially heat treated with $^1/_2$ the nose part quenched and drawn to give a 285–310 Bhn on one-half of the casting, including the nose part which is subjected to highly concentrated forces.

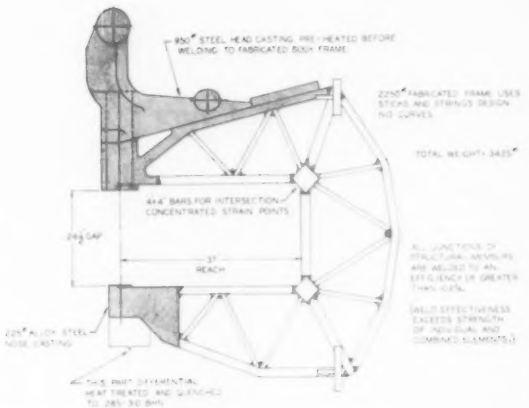


Fig. 2—Details of welded frame and castings

After fabrication the 3400-lb weldment-casting was put in a 1175° F heat treating furnace and normalized to relieve the stresses in the metals created by welding and other heat-treating operations.

This weldment-cast structure has since been tested and found very able to withstand two times the stresses it will be under when used in the field.

Hard Surfacing Doubles Tractor Roller Life

Cast steel rollers on a crawler tractor used in a northern California logging operation are lasting twice as long when protected with a welded overlay of hard-surfacing build-up wire. The welding is done by Consolidated Machine & Tool Co., Oroville, Calif.

The rebuilt parts are single-flange rollers from a crawler type Allis Chalmers tractor. They operate continually under severe abrasive conditions in sand, water and dirt. The overlay achieved with the hard-surfacing wire will not chip or spall in service. In addition, friction is reduced, which lengthens service life of track rails and other parts that come in contact with the overlaid surfaces. The method used is basically a reclamation operation. New rollers, therefore, are allowed to wear in before being given the overlay protection. The rollers can be reclaimed by rebuilding again and again, adding further to the economy of the operation.

Worn rollers are first thoroughly degreased. No machining is necessary because the parts are usually allowed to wear $^1/_8$ to $^1/_2$-in. undersize before being sent in for rebuilding. Prior to welding, a wire brush is used to remove dirt or scale from the surfaces to be rebuilt.

With the roller mounted in a special rotating positioner, build-up wire is applied to bring the roller back to original diameter. The wire used is a medium carbon alloy steel. It is especially designed for application by semiautomatic electric arc build-up techniques using a semiautomatic welding machine. Once the arc has been struck, wire is continuously fed from the machine onto the worn roller surface.

In the setup used at Consolidated Machine & Tool, the wire is moved laterally by means of the mechanical traversing arrangement. A setup of this type combined with the semiautomatic welder cuts welding time substantially.

Hard surfacing of worn cast steel rollers for crawler tractor

Based on a story from Wall Colmonoy Corp., Detroit, Mich.

Soldering Machine Revolutionizes Radiator Manufacture

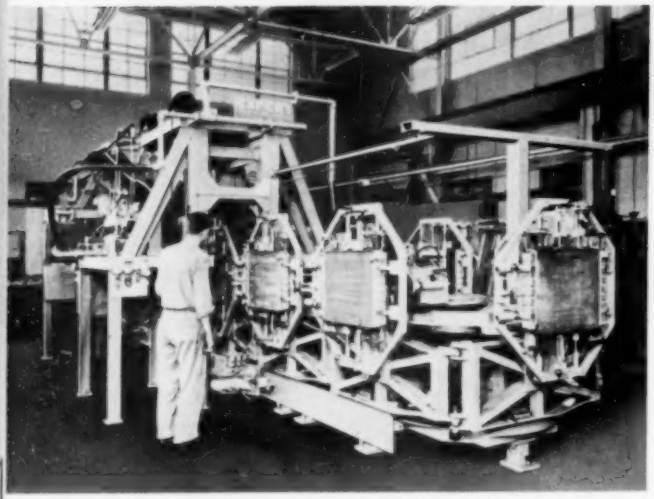


Fig. 1—Expert automatic soldering machine which is designed to produce 206 radiator assemblies per hour at 80% efficiency

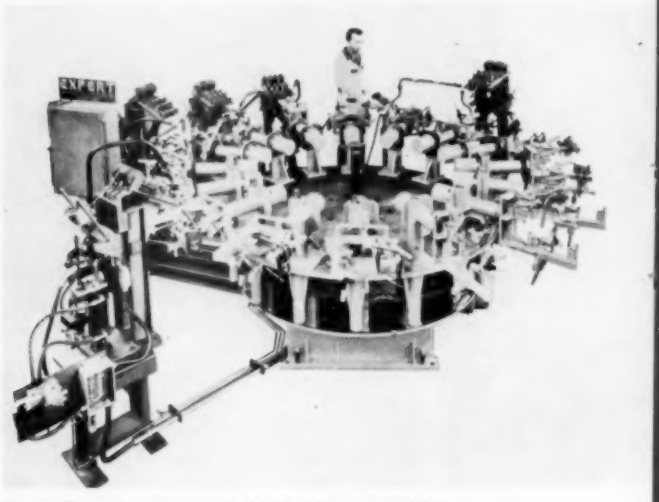


Fig. 2—Expert automated soldering machine which automatically solders connections and brackets to radiator supply tanks

The application of 2 lb of solder to leak-proof an automobile radiator has always been 90% hand work, requiring a fair amount of human skill but also subject to misjudgement.

To improve quality and manufacturing processing, provide better quality soldered joints together with predictability and repeatability of the soldered joints and to increase production rates of automobile radiator assemblies, it was judged necessary to design and build an automatic automobile radiator soldering machine and a supply tank soldering machine.

At two of the plants where the radiator machine is installed, quality control standards call for a minimum 0.200 in. depth of solder penetration on the radiator tank joints, and a minimum $2^1/_2$ in. square area of solder penetration under the lap joints on the side support brackets. The machine has cut the rejects on these tightened standards by a factor of 7. Prior to machine installation it was impossible to meet quality control standards and yet maintain efficient production rates. Earlier production techniques had utilized conventional hand soldering with removal and replacement of the radiator assemblies from a chain conveyor, and later evolved into semi-automatic soldering stations placed at various intervals along the conveyor.

The new machines are designed to produce radiator assemblies at a variable production rate. The calculated maximum capacity of the radiator machine is 206 per hour at 80% efficiency and the calculated maximum production rate of the supply tank machine is 238 per hour at 80% efficiency.

Based on a story from Expert Welding Machine Co., Detroit, Mich.

Radiator Soldering

The radiator machine automatically solders two tanks and the two side support brackets to the radiator core.

In operation, the operator sets a trip mechanism to correspond with a particular size radiator. This mechanism then contacts a limit switch which automatically adjusts the solder feed mechanism and heat source, to line up with the specified radiator size.

To begin automatic soldering operations in the assembly of automobile radiators, the prefluxed core and both tank subassemblies are manually loaded and clamped in the fixture in station 1. The assembly is then automatically transferred to idle station 2. In station 3, one tank is automatically soldered to the radiator core. During the soldering operation, the part is heated by gas burners to the proper soldering temperature. The burner heads are hydraulically positioned in relation to the radiator, and gas flame increased from minimum pilot flow to maximum. Since three different widths of radiator are soldered, proper burner position is controlled by three limit switches. A dog on each fixture is located in one of three holes according to the width radiator it holds, and activates the proper limit switch.

The solder wire is then automatically fed from rolls to the proper joint positions on the tank core assembly by all-mechanical solder feed mechanisms. The solder contacts the heated part and flows by gravity and capillary action around the joints producing a completely sweat soldered joint.

After cooling and rotation, the opposite tank is automatically soldered in station 6 to the radiator

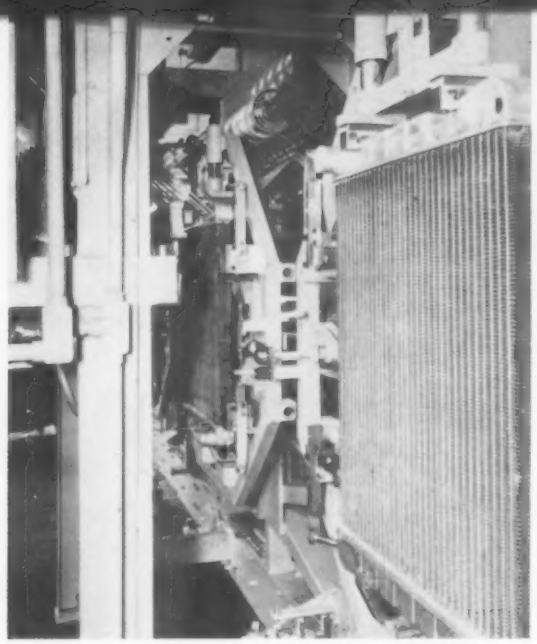


Fig. 3—Radiator with one completely soldered tank being indexed from soldering station 3 to station 4. Note multiple limit switch arrangement at bottom of photograph for positioning solder feed and heat jets for different size radiators

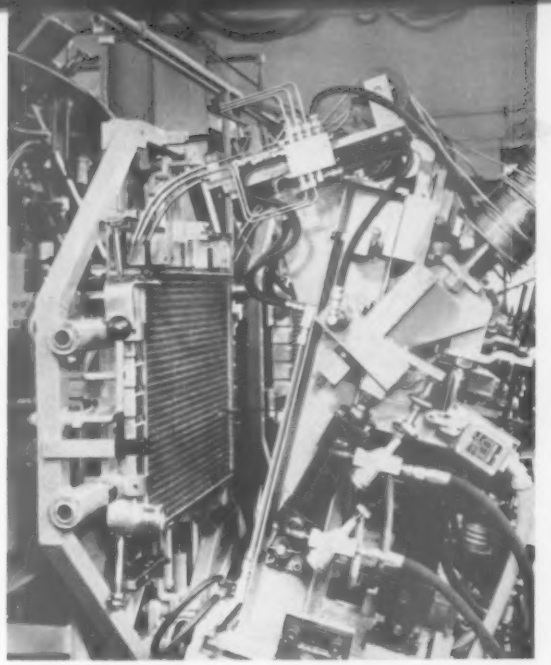


Fig. 4—Automatic soldering operations being performed in a station to assemble one side support bracket to radiator core

core in the same manner as in station 3. After cooling, the radiator is then transferred to other stations where support brackets are automatically soldered to the radiator tank. During soldering, the joints to be soldered are heated by gas burners to the proper soldering temperature. The solder wire is then automatically fed to the proper joint position where it contacts the heated part and flows around the joints producing a completely sweat soldered joint.

Supply Tank Soldering

Prefluxed supply tanks, water connections and brackets are manually loaded in the fixtures at the front of the machine. The assemblies are then indexed through the five soldering stations where the connections and brackets are automatically soldered to the tanks. The machine is indexed from station to station by a standard cam index mechanism.

During the soldering operation, the joints are heated to the proper temperature by gas burners. The solder wire is then automatically fed to the proper joint positions by solder feed mechanism. The solder contacts the heated part and flows in the joints to provide a completely sweat soldered joint.

Demineralizer for Nuclear Destroyer Requires Careful Planning

Tough welding jobs are encountered by shipyards and their subcontractors in this era of nuclear shipbuilding. Thus specifications for reactors and auxiliary equipment often require the welding of special alloys and stainless steels in heavier sections than most shipbuilders have experienced in conventional ship construction. Because sound welds are essential, carefully planned welding procedures and use of the best welding materials are of utmost importance.

An example of what can be accomplished is shown by the recent fabrication of a prototype 8-ton, all-

Based on a story from the Arcos Corp., Philadelphia, Pa.

Fig. 1—Stainless steel shell section of a DIG demineralizer, designed for the power plant of a nuclear destroyer, is shown on weld positioner

stainless steel (Type 304) demineralizer by Avery & Saul Co., Cambridge, Mass., for installation in a nuclear-powered destroyer being built for the U. S. Navy.

The demineralizer, to be used in the primary system of the destroyer, measures 24 in. diam x 7 ft. high and has a wall thickness of better than 2 in. It was designed to the Navy reactor code for nuclear service.

To fabricate the demineralizer, three different welding processes were used: tungsten-arc, submerged arc, and the EB weld insert process. By using the EB weld insert process for the root pass in joining the cover and bottom sections to the shell, welding time was substantially reduced. A smooth, uniform inner bead was assured.

The EB weld insert process involves the use of a preplaced weld insert which is completely fused by use of a conventional inert-gas-shielded tungsten-arc torch. The insert permits a full penetration root pass even though the welding is actually done from one side only.

The gas tungsten-arc process was used for the first few layers, with suitable filler material. The submerged arc process was used to complete the joints.

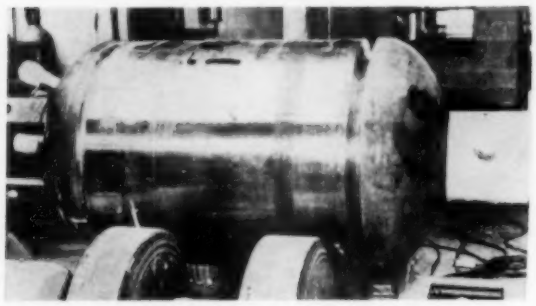


Fig. 2—Cover and bottom sections of the demineralizer have been welded to the shell. EB weld insert process was used to make the root pass of the closure weld

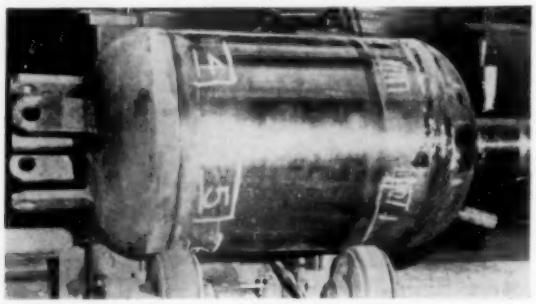


Fig. 3—Joints were completed by the submerged-arc-welding process. The prototype demineralizer weighs about 8 tons, measures 24 in. diam and 7 ft high. The unit was designed to Navy specifications for nuclear service

Low-Cost Cost Reductions

Hibben and Company, Chicago, Ill., steel plate fabricators and erectors needed no elaborate training or fancy fixtures to double production volume and lower production costs—just a semimechanized vapor shielded welding unit and two hours of practice.

Based on a story from the Lincoln Electric Co., Cleveland, Ohio

This method of arc welding increased production of 229 blast furnace cooling system boxes from $5\frac{1}{2}$ to over 11 completed assemblies daily. Work grew and production facilities were the same. Only the method of welding was changed. This simplified approach to semiautomatic welding combined the speed and economy of mechanization with the flexibility of manual stick electrode arc welding.

Key to the new vapor shielded method is the tubular self-shielding mild steel electrode wire, fed mechanically through a 24 oz welding gun. This electrode is continuously supplied from a 50 lb reel mounted in a remote console. Weld stopping and starting is actuated by a trigger on the welding gun, welding current being regulated by the wire feed speed.

Welding with tubular self-shielding mild steel electrode wire which is fed through manual welding gun

In this application, involving deposition of $19\frac{1}{2}$ ft of $\frac{5}{16}$ in. laps and fillets on the 5 pretacked, $\frac{7}{8}$ in. thick plate members of the cooling box, current averages 500 amp d-c positive at 32 arc volts. Travel speed is in the range of 18 ipm. Fit-up is not critical.

The tubular electrode wire contains materials for shielding, fluxing, and deoxidizing, eliminating the need for external fluxes or shielding gas. Slag coverage of the welding bead is easily chipped or wire brushed.

Society News

AWS Staff Moves to New Quarters

More than 40 years of occupancy at the Engineering Societies Building in New York City ended for the AMERICAN WELDING SOCIETY over Labor Day weekend. On Friday afternoon, Sept. 1, all 38 AWS staff members cleared off their desks for the last time in the old quarters. At 9:00 A.M. on Tuesday, Sept. 5, they reported for work at the new United Engineering Center where desks and working materials were in place. Within an hour, work was beginning to proceed normally.

The move over Labor Day weekend involved 18 major societies in addition to AWS and was the climax to weeks of behind-the-scenes planning. It was preceded by a move on the part of what is the largest public library in the Free World devoted to engineering—the Engineering Societies Library. This involved the transfer of 180,000 volumes, 27,000 maps, 10,000 indexed bibliographies and many thousands of technical papers. In the case of AWS, the move called for the transfer of desks and chairs, the contents of 250 file cabinets, tables and 100 large cartons of printed material. The actual move by AWS was carried out in the course of one evening.

The move dates back to 1957 when AWS officers and directors initiated careful and extensive studies of the relative advantages of alternate plans and locations for national headquarters. It was finally agreed that acceptance to establish headquarters in the new United Engineering Center would be most economical, would result in most efficient operation and would justify unprecedented pride and prestige as a result of the associated societies and the fine facilities.

The AWS will enjoy exactly the same privileges and responsibilities as all other groups occupying the building. Meeting and exhibit rooms, dining facilities and one of the world's most complete engineering libraries will be housed in this building.

However, the Center is not to be a gathering place for engineers—such as those found in many other cities—where the buildings serve as a focus for numerous social and professional meetings and assume the character of an engineers club. It is not designed to handle the major meetings of the societies.

The Center will serve as the headquarters business office for some 600 staff members of the participating groups; it will accommodate the editorial staffs concerned with the preparation and publication of periodicals, papers, books, manuals, codes and standards; it will permit mechanization with modern equipment and thereby improve certain services to members; it will house the Engineering Societies Library equipped to serve the library search needs of the 250,000 members; it will stand as a world-wide symbol of the importance of engineers.

District Meeting

The annual meeting of District Eight was held on July 1st at the Brown Palace Hotel in Denver, Colo.

District Director G. O. Bland called the meeting to order at 9 : 00 A.M. Those attending included: C. L. Rearden, L. L. Thompson, and J. M. Goldsmith from the Kansas City Section; Chairman E. C. Burrow of the St. Louis Section; J. W. Markwell from the Northwest Section; and six members of the Colorado Section.

The meeting ended in late afternoon, whereupon those at the meeting and their wives boarded a bus

AWS DIRECTORS-AT-LARGE

Term Expires	1962	1963	1964
	W. H. Hobart	R. B. McCauley	J. E. Dato
	F. G. Singleton	John Mikulak	A. N. Kugler
	C. B. Smith	E. F. Nippes	T. E. Jones
	J. R. Stitt	R. D. Stout	E. C. Miller

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District No. 2•Middle Eastern	C. L. Kreidler	District No. 7•West Central	L. L. Baugh
District No. 3•North Central	J. W. Kehoe	District No. 8•Midwest	G. O. Bland
District No. 4•Southeast	J. M. Shilstone	District No. 9•Southwest	C. L. Moss, III
District No. 5•East Central	P. J. Rieppel	District No. 10•Western	D. P. O'Connor
		District No. 11•Northwest	W. J. Ericksen

AWS PAST-PRESIDENT DIRECTORS

R. D. Thomas, Jr. C. I. MacGuffie

for a trip through mountains and a steak dinner at the Greystone Ranch. Following dinner, they returned by bus to Denver by way of Central City, which was once famous for gold mining.

Russian Electroslag Welding Film

Through courtesy of the Arcos Corp., the SOCIETY has obtained two prints of a 16 mm black-and-white one-reel movie film in sound showing electroslag welding in the USSR. Both prints are available, free-of-charge, for showing at AWS Section meetings and may be obtained for this purpose by writing to the WELDING JOURNAL. The sound tract is in English, and the movie runs for 20 min.

The film was first shown in this country at the 42nd Annual Meeting by Prof. B. E. Paton of the USSR in connection with presentation of his paper on electroslag welding. At that time it was in two parts on 35 mm film. Thus, after negotiation with the Amtorg Trading Corp., it was necessary to convert the film to 16 mm so that it could be shown in this country in sound and with one reel.

The film quickly explains the principles of electroslag welding in its different forms. Scenes include the Paton Institute of Welding in Kiev and numerous interior views of heavy industrial plants in Russia. Viewers will be particularly interested in the massiveness of parts made by the Russians where electroslag welding is applied.

The movie may also be obtained for showings before organizations other than AWS by writing to Arcos Corp., 1500 S. 50th St., Philadelphia 43, Pa.

Last Day in Old Quarters

Miss Snyder (left), Mrs. Jacobs (center), and Mrs. Silver begin their last day—Friday, Sept. 1—in old quarters at 33 West 39th Street in New York City

Journal staff members reach for boxes to begin packing personal effects and office supplies

Late in the day, George Adame (left), Tom Buckley (center), and Gene Schneller finish packing the last of AWS supplies

National Secretary F. L. Plummer reviews moving situation with other AWS staff members. Left to right are: F. J. Mooney, F. L. Plummer, W. Waldron, and E. Krisman

Progress In Welding Equipment

National President A. F. Chouinard holds a gas welding tool (left) made 60 years ago and the latest in oxyacetylene torches

Business as usual: F. J. Talento of Journal staff talks with advertiser

Scene in lobby of Engineering Societies Building at 5:00 P.M.

UNITED ENGINEERING CENTER

Last minute touches on the new United Engineering Center are speeded through a motorized scaffold on tracks for the use of window cleaners

Honor Sections

Section	Goal, %	Section	Goal, %
Oklahoma City	138	Maryland	107
New Jersey	133	Niagara Frontier	107
Louisville	130	Sangamon Valley	107
Mahoning Valley	121	Bridgeport	105
Kansas City	120	San Antonio	105
Worcester	120	Syracuse	105
Baton Rouge	119	Cincinnati	104
Birmingham	118	Providence	104
Northwest	117	Northern N. Y.	103
North Texas	115	Chicago	102
Hartford	114	N. E. Tennessee	102
Wichita	113	Puget Sound	102
Philadelphia	112	Saginaw Valley	102
Colorado	111	Tulsa	102
Detroit	111	San Diego	101
Albuquerque	110	Chattanooga	100
Dayton	110	Eastern Illinois	100
New Hampshire	110	Long Beach	100
Pascagoula	110	Los Angeles	100
Richmond	110	Madison-Beloit	100
Western Mass.	110	Michiana	100
Holston Valley	109	Mobile	100
New York	109	Nashville	100
Rochester	109	N. Central Ohio	100
St. Louis	109	Olean-Bradford	100
Boston	108	Salt Lake City	100
Long Island	108	San Francisco	100
Toledo	108	Santa Clara Valley	100
Iowa	107		

Pledges Needed to Meet Goal

Section	Needed	Section	Needed
Pittsburgh	25	New Orleans	350
Carolina	64	Peoria	365
Anthony Wayne	150	Susquehanna Valley	350
Shreveport	155	York-Central Pa.	375
Iowa-Illinois	180	Portland	385
Washington	180	Houston	400
Arizona	200	Sabine	400
Nebraska	200	Lehigh Valley	415
J. A. K.	235	Fox Valley	450
Orange County	275	Stark Central	495
Northwestern Pa.	280	Columbus	770
Indiana	312	Milwaukee	832
South Florida	330	Cleveland	900
Western Michigan	330		

Window Cleaner's Paradise

Pledges continue to move sections up the ladder to reach their goal. The majority of sections have attained 100% or more of their assigned quotas and have been placed on the Honor Roll. The last count shows AMERICAN WELDING SOCIETY pledges to be at 92% of goal.

KEEPING YOU POSTED

By Fred L. Plummer

● These notes are being written just two weeks before the scheduled move of the AWS headquarters to the new United Engineering Center. Early in September, the five founder engineering societies, several associate societies including AWS and a number of joint agencies such as Engineering Foundation, EJC, WRC, Engineering Library (perhaps the most complete anywhere), Engineering Index and others representing about 300,000 individual members, will establish their headquarters in the new twenty-story tower. The combined staffs of these groups include almost six-hundred people.

● In effect, before you read this article, the new AWS address will be 345 E. 47th Street, New York 17, N. Y. and the new telephone number is PLaza 2-6800. Formal dedication of the Center is now planned for early November with past president of the USA Herbert Hoover serving as Honorary Chairman. AWS members are urged to visit the new offices when in New York. A special AWS open house will be planned at a later date.

● As of August 15th, fifty-eight AWS Sections had pledged their full quota to the UEC building fund and two others needed only a few dollars to meet their quotas. Of the remaining twenty-four Sections, only three needed more than $500 in pledges to meet their quotas. All five founder societies and two of the associate societies have pledged amounts in excess of their individual quotas, which total $3,395,000.

● On July 25th, your Secretary held a luncheon conference with Ray Townsend, Ed Dato and Exposition Manager R. T. Kenworthy to discuss welding expositions sponsored by the Santa Clara Section to serve the San Francisco Bay Area and to explore ideas for possible expositions to serve this and other West Coast areas in the future.

● The following day a telephone conference was held with Vice President and Technical Council Chairman J. H. Blankenbuehler concerning recommendations of your Technical Secretary E. A. Fenton covering the translation, reproduction and distribution of two Russian books dealing with "electroslag" and "friction" welding. The Technical Council has now approved this action and the work is proceeding rapidly.

● Your Secretary traveled to Philadelphia on July 28th for conferences with Exposition Committee Chairman J. E. Norcross and Past President R. D. Thomas, Jr. Current chairmanship responsibilities of Mr. Thomas include the Administrative Council, the National Nominating Committee, the Honorary Membership Committee, the Sustaining Membership Committee, IIW Commission XII and others in addition to membership on the Executive-Finance Committee and special Pension and Group Insurance Committees.

● Seven members of a special "Productivity Team on Welding" from India including leader R. Ghosh and members S. P. Chitnis, S. V. Nadkarni, R. D. Singh, M. P. Singh, C. L. Trehan and H. J. Lentin met with your Secretary on July 31st and lunched at the N. Y. Engineers' Club. This visit was part of a six-week study of welding techniques employed in industrial production and in construction in the U. S. The project was sponsored by our National Productivity Council and Manager W. R. Boynton accompanied the group. During the day WRC Director Ken Koopman, IIW Past President H. Biers, IAA Representative T. E. Willoughby, AWS Technical Secretary E. A. Fenton and other staff members joined your Secretary in discussing welding activities with the members of this group of responsible Indian industrial executives, technicians and government officials.

● Late July and early August, important visitors either in person or by telephone included: Don Howard, chairman of our active Missiles and Rockets Welded Fabrication group; Al Pearson, Past Director, in New York for a conference with a customer covering the construction of a unique welded building; R. Elfvin, program chairman of the St. Louis Section; I. E. Oehler of Warren, Ohio, to discuss an important new report on flash welding; John W. Mortimer, Past Director, who has been associated with Pratt and Whitney of Hartford for the past five years; Malcom Priest and Mrs. Priest; C. I. MacGuffie, past president, chairman of our Convention Committee and of a special sub-group of our Manufacturers' Committee which is reviewing all factors which influence the selection of sites, the frequency, space allotment, eligibility of exhibitors, selection of facilities and services for our National Welding Expositions; H. Thielsch and others who are heading committees responsible for the preparation of chapters for the fifth and final section of the Fourth Edition of the Welding Handbook, which will be distributed at the end of this year; George D. Farmer, Jr., U. S. Army Engineer Research and Development Laboratories at Fort Belvoir, interested in evaluating equipment for the automatic welding of pipe in the field; WRC Director Ken Koopman; and President A. F. Chouinard on several occasions.

● Your Secretary has met with special committees concerned with various operating problems in the United Engineering Center: common service facilities; use and cost of meeting rooms, exhibit space and special dining rooms; office and lunch hours; coordination of moving and installation of new equipment; and a wide range of similar problems.

● On August 30th, your Secretary and Mrs. Plummer will move from Stamford, Conn., to a new apartment building very close to the United Engineering Center. Our new address will be Apt. 14-B, The Continental, 321 E. 48th Street, New York 17, N. Y.

● President Chouinard visited Purdue University during the week of August 14th to assist in the annual training program conducted there for the teachers who carry on the apprentice training work of the United Association of Plumbers and Pipe Fitters.

● Membership Activities Chairman A. C. Axtell, Sustaining Membership Chairman R. D. Thomas, Jr., Assistant Secretary F. J. Mooney, who is now in charge of all membership recruiting activities, and your Secretary met on August 17th to complete plans and set goals for local and national membership drives during the current fiscal year. Mr. Mooney will visit three areas, where new Sections are being organized, before attending the National Fall Meeting in Dallas. Following that meeting he expects to vacation in Florida during October.

● Vice President C. E. Jackson, after spending most of September in Australia, will address our AWS Hawaii Section in Honolulu at a dinner meeting scheduled for September 29th. J. F. Stacy is Chairman of this newest AWS Section.

● The National Fall Meeting in Dallas will become history shortly before these notes are printed in the October issue of the Journal. Texans C. L. Moss, III, E. T. Mai, J. R. Stewart, Fred Salmons, M. E. Eliot, W. H. Irwin, R. F. Skipwith and many others will have been largely responsible for the rewarding activities which are now scheduled.

● Our eleven District Directors have organized in each district a nominating committee and a Meritorious Certificate Awards Committee. Each member of the Society can suggest possible nominees to these committees. This can usually be done easily by suggesting names to the Chairman of your Section.

● During the past fiscal year the Saginaw Section challenged each of the active sections of AWS to an attendance contest, offering a 25 lb bag of beans and a recipe for famous Michigan Bean Soup against some equivalent edible item together with appropriate recipe for cooking. Three Sections—Nashville, Northern New York and Rochester—accepted this challenge. Average attendance figures at technical meetings, expressed as percent of total members, during the 1960-61 fiscal year for these four Sections were as follows: Saginaw Valley, 54; Nashville, 42; Northern New York, 40; and Rochester, 39.

● Long-time AWS member in Cleveland, E. T. Scott, proudly announces a new grandson—Andrew William Scott—with the famous A. W. S. initials.

● At the annual ASM meeting in Detroit on October 26th, President Chouinard and Vice President Jackson will preside over two special technical sessions devoted to welding. The first, dealing with new welding processes, will include papers by W. H. Wooding on electroslag welding, by E. A. Franco-Ferreira on electron beam welding and by M. B. Hollander on friction welding. The second, covering gas-shielded welding processes, will include papers by P. J. Rieppel, W. B. Blackburn and T. W. Shearer.

● President Chouinard and your Secretary have planned a number of visits with AWS Sections during the next several months. October visits include the following: 2, Oklahoma City; 3, Tulsa; 16, Rochester; 17, Manchester, N. H.; 19, Worcester, Mass.; and 25-26, Detroit.

● Your Secretary, who is also IIW Vice President, and Mrs. Plummer leave for Europe about mid-October to attend a meeting of the Executive Council of the IIW in Paris and later to vacation in Greece, Italy and Turkey.

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●

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EDUCATIONAL ACTIVITIES

Dallas Meeting

The National Fall Meeting provides an excellent opportunity for an evaluation of our programs for the coming year and to determine our progress in the specific activities.

The various AWS Councils held meetings and heard progress reports on the WELDING HANDBOOK, the Information Center, promotion campaigns for the coming year, and the Educational Activities Program.

Welding Handbook

Section V, the last section of the Fourth Edition of the WELDING HANDBOOK, was reported to be in good shape with all copy received. If all goes according to schedule, the manuscript should be in the hands of the printer this month and the Section available for distribution in January 1962.

The WELDING HANDBOOK Committee, under the chairmanship of J. J. Chyle, held a meeting at Dallas to decide upon changes which should be made in the fifth Edition of the HANDBOOK. Committees have already been formed and are busily engaged revising the material in Section I. This constant effort to keep the HANDBOOK up-to-date and to provide the latest and most authoritative information is having the desired results. More WELDING HANDBOOKS are being sold than at any time in the history of the SOCIETY. More companies, and a greater number of people within these companies, are using the HANDBOOK as their guide on all welding matters. A recent visitor from abroad revealed that his government would purchase no welding equipment which was not mentioned in the WELDING HANDBOOK.

Such comments indicate the tremendous responsibility involved in the preparation of material, and also the thanks due to those individuals and companies who work so tirelessly to prepare the various Sections of the HANDBOOK.

Education

The Education Open Meeting has become a regular feature at the National Fall Meetings. It provides an opportunity to discuss Section Educational problems and to give Section Chairmen the help they need in organizing courses and other educational activities.

Chairman E. C. Miller reported on the educational program scheduled for the coming year and on the various activities in progress:

"Opportunites in the Welding Industry"—This booklet is still in great demand. Supplies are very low and a third printing has become necessary.

AWS Training Manual of Arc Welding—This manual has been selling steadily ever since it was published. Many companies use it as a company training manual.

Arc Welded Joints—This was a NEMA sponsored activity and we did the promotion and distribution. The booklet is distributed free to teachers at college level and has enjoyed wide acceptance.

Recommended Practices for Welding Departments in Public Schools—Task Forces are working on this project. A special effort is being made to complete the project during the coming year.

In-Plant Training Course—The purpose of this course is to make material available in such a form that company personnel could present courses on specific aspects of welding. Sections, or items, would be taken from the master outline to make a complete course on a given subject. Substantial progress has been made and the Committee hopes to have material available for distribution this year.

Purdue Refresher Course—This activity is conducted yearly at Purdue University and is primarily concerned with teaching welding instructors the latest practices in both teaching and welding. It is not sponsored by AWS, but AWS members are concerned with much of the instruction. Excellent results were obtained again this year.

Educational Lecture Series—This Series has become a feature at National Spring Meetings and is very well received by an increasingly large audience. The lecturer for next year has been approached and his acceptance is expected.

AWS School of Welding Technology—Last year the AWS School of Welding Technology held three courses: Welding Metallurgy, Inspection of Welding, and Welded Piping for Industrial Piping Systems. This year we plan to hold three courses, two in November and one in February of 1952. The subjects —tentative at present—will be Gas Shielded-Arc Welding, Inspection of Welding and Welded Structural Design.

These courses have been very successful and enabled us to provide our Sections with complete outlines and textbooks. With the aid of these outlines and texts, Sections have been able to present excellent courses with the minimum of preparation.

Speakers Directory—The new Speakers Directory was displayed at the Open Meeting and has since been distributed to all Sections.

AWS Training Manual of Oxy-acetylene Welding—This manual is in preparation and a first draft will soon be available for the Committee.

Film Directory—It was announced that the Film Directory would be revised this year.

Promotion and Publicity

There are certain techniques used in the preparation of promotional material and certain accepted methods of presentation. If these are followed, there is a much greater chance of the material being published. These subjects were discussed in detail at the Open Meeting for the benefit of Section Publicity Chairmen and others interested in promotion.

The Section Publicity Kit had been brought up-to-date and new material added. This kit was distributed at the Meeting and its uses explained. Publicity Chairmen not present will receive their copies shortly.

Promotion has already started on the 1962 Show at Cleveland and Sections should be organizing their Committees now for National Welded Products Month. If the promotion is to be successful, members should be assigned to: proclamations, companies' participation, displays and newspaper publicity

To Hold Welding Institute for High School Teachers

The Second Annual Welding Institute for the high school welding

instructors will be held at the University of Wisconsin and the Madison Vocational School on Saturday, October 21, 1961. This institute is through the combined efforts of the Madison-Beloit AWS Section, the Mechanical Engineering Department of the University, the University Extension Center and the Madison Vocational School.

Following registration between 8:00–8:30 A.M., the morning session will be held in the Wisconsin Center, 702 Langden St. Featuring the morning session will be a welcome by Assistant Professor N. R. Braton of the University of Wisconsin; a talk on "What's New in Welding for the Secondary and Vocational Schools" by Ted Jefferson, publisher of *Welding Engineer*, a talk on aluminum welding and brazing by H. E. Adkins, Kaiser Aluminum Co.; and "What to Look for in Buying Electric Welding Equipment for the High School" by H. B. Cary, Hobart Brothers Co.

The afternoon session will be held at the Vocational and Adult School in Madison. F. Theiler, director of welding at the school, together with M. Stavig of All-State Welding Alloys Co. and G. Duchon of the University of Wisconsin will demonstrate different aspects of welding. The session will close with a panel discussion and with the presentation of certificates by Professor G. Sell, University of Wisconsin.

The registration fee is $5.00 and includes lunch.

Engineers' Council to Meet

The Engineers' Council for Professional Development recently announced that its 29th annual meeting would be held during Oct. 2–3 at the Sheraton Seelbach Hotel in Louisville, Ky.

The local chairman is Dr. R. C. Ernst, dean of the Speed Scientific School, University of Louisville.

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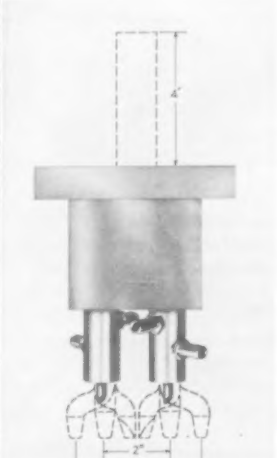

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Models are made for mounting in a welder arm (above) or for bolting to a press welder platen (left).

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SECTION NEWS AND EVENTS

As reported to Catherine M. O'Leary

Hawaii Section Receives Charter

A new section was welcomed into the ranks of AWS in July as *Hawaii* Section, Honolulu, Hawaii, successfully petitioned for official recognition. The action of the Board of Directors which was taken on July 6 brings to 88 the number of active sections in the growing roster of AWS.

Officers reported for the present term are as follows: Chairman, J. F. Stacy; 1st Vice Chairman, D. H. Saunders; 2nd Vice Chairman; H. T. McConnaughey; Secretary, J. T. Lee; and Treasurer, J. E. Horner. Executive Committee members are T. T. W. Chun, W. R. Townsend, C. N. Sigler, W. Darr, N. H. Muraoka, and L. P. Pauls.

The election of officers took place at a meeting held on July 27 at Elliott's Chuck Wagon in Honolulu. Following the election of officers, J. F. Shoemaker, vice president in charge of business research at the Bank of Hawaii, presented an interesting educational talk on the economy of Europe in relation to Hawaii. His talk was illustrated with maps and charts.

L. P. Pauls won a door prize consisting of an electric drill which was donated by the Honolulu Iron Works through Mr. W. Parr.

NEW CHAIRMEN MEET IN HONOLULU

On his way to Kwajalein, Lt. E. Wilson, new chairman of the Greater Huntsville Section, is greeted by Chairman J. Stacy of the Hawaii Section

Illinois

GOLF STAG

North Aurora—The *J.A.K.* Section held its first annual golf stag at the Fox Valley Country Club in North Aurora on August 5th.

This event was attended by 80 golfers, members and guests. The weather cooperated, and it turned out to be a beautiful day for golfing. Everett Hawse of Aurora with a score of 68 was the Medalist and received a trophy for his low score.

A smorgasbord dinner was served in the clubhouse. After dinner a drawing was held for prizes.

This event was so well received that the officers decided to make this a yearly event; the next outing will be held next August.

New Jersey

ANNUAL DINNER DANCE

Newark—On Saturday, May 20th, the *New Jersey* Section held its annual dinner dance and installation of officers at the Essex House in Newark.

Approximately 160 members and guests enjoyed the cocktail hour and excellent dinner which followed. There was also a full and very enjoyable evening of dancing and entertainment.

Program Chairman Ken Richter deserves hearty congratulations for a job well done.

The newly elected officers are: Chairman, S. L. Sullivan; Vice-Chairman, E. F. Bowden; Secretary, J. Flannery; Treasurer, A. C. Axtell. New members on the Executive Committee are: A. F. Fleury, K. E. Richter and A. J. Newman.

Texas

ANNUAL LADIES' NIGHT

San Antonio—The *San Antonio* Section held its annual ladies' night on Wednesday, August 9th, at the Pearl Corral with over 250 members, their wives and guests present. A barbecue dinner was served, followed by a style show of the latest fall fashions, and dancing.

NEW JERSEY DINNER DANCE

Scene at the Essex House in Newark, N. J., on May 20 when the New Jersey Section held its annual dinner dance

A small handful of the 160 members and guests who were present at the Essex House on May 20. Program Chairman K. E. Richter is shown in the center with Mrs. Richter

SECTION MEETING CALENDAR

OCTOBER 5

CHICAGO Section. Chicago Bridge & Iron Co. Dome. 4th Annual Educational Lecture Series: Welding Processes. Third Session—Brazing, J. F. Rudy, Armour Research Foundation.

NORTHERN NEW YORK Section. Hot Shoppes, Route 9, Albany, N. Y. "Future Telephone Communication Plans," W. R. Rooney, New York Telephone Co.

OCTOBER 9

BOSTON Section. Visit to the MIT Laboratories. Speaker: Dr. C. M. Adams, Jr.

OCTOBER 10

COLORADO Section. "Fabrication of Aluminum," film by Reynolds Aluminum Co.

PITTSBURGH Section. Educational Course "Welding Metallurgy." Lecture 3.

WESTERN MASSACHUSETTS Section. Oaks Inn, Springfield, Mass. Dinner 6:30. Meeting 8:00 P.M.

OCTOBER 12

CHICAGO Section. Chicago Bridge & Iron Co. Dome. 4th Annual Educational Lecture Series: Welding Processes. Fourth Session—Submerged-Arc Welding, L. J. Christensen, Chicago Bridge & Iron Co., and W. R. Root, Taylor Forge & Pipe Works.

J.A.K. Section. Aurora, Ill. "Inert-Gas Metal-Arc Welding."

KANSAS CITY Section. Wishbone Restaurant. "Joining Aluminum" Charles Brown, All-State Welding Alloys Co.

NORTH TEXAS Section. Amon Carter Field. 6:30 P.M. Dinner and technical session. Speaker: Wayne Claflin, Ampco Metals, Inc.

RICHMOND Section. Richmond, Va. Speaker Wally Rudd, Vice Pres., New Rochelle Thermatool Corp.

ST. LOUIS Section. Ruggeri's Restaurant. "Large Single Span Roof Structure Design," Louis Bass, Roof Structures, Inc.

OCTOBER 16

ROCHESTER Section. Liederkrantz Club. "Progress Report on the Flux-Cored CO_2 Process," A. L. Chouinard, National Cylinder Gas Div., Chemetron Corp.

OCTOBER 17

HARTFORD Section. Villa Maria. "Aluminum Fabrication," Ivan A. MacArthur, Olin Mathieson Chemical Corp.

NEW JERSEY Section. Essex House, Newark, N. J. Dinner 6:30. Meeting 8:00 P.M.

OLEAN-BRADFORD Section. Castle Restaurant, Route 17, Olean, N. Y. Dinner 7:00. Meeting 8:00 P.M. "Dual Shield," M. B. Prisuta, National Cylinder Gas Co.

PITTSBURGH Section. Educational Course "Welding Metallurgy." Lecture 4.

OCTOBER 18

HOUSTON Section. "Welding Quenched and Tempered Plates," Thomas J. Dawson, Ingalls Shipbuilding Corp.

PITTSBURGH Section. "Control of Fabricating Costs in Manufacturing Operations," D. L. Brugioni, Caterpillar Tractor.

TOLEDO Section. Toledo Yacht Club. Dinner 6:30. Meeting 7:45 P.M. "Welding Fixtures," C. B. Herrick, C. B. Herrick Co.

OCTOBER 19

CHICAGO Section. Chicago Bridge & Iron Co. Dome. 4th Annual Educational Lecture Series: Welding Processes. Fifth Session—Submerged-Arc Welding, L. J. Christensen, Chicago Bridge & Iron Co., and W. R. Root, Taylor Forge & Pipe Works.

LOS ANGELES Section. Rodger Young Hall. 6:30 P.M. Panel on "Welding in Building Construction": Dwight Miller, Dept. of Building and Safety; Ray Osborne, Osborne Laboratory; Harold Doudny, Consulting Structural Engineer, and Al Collins, Kaiser Steel Moderator.

SABINE Section. "Welding Quenched and Tempered Plates," Thomas J. Dawson, Ingalls Shipbuilding Corp.

STARK CENTRAL Section. Pllanaris Palm Garden, Alliance, Ohio. "Future Metal Working, Welding, etc."

OCTOBER 20

CHICAGO Section. Milner's Restaurant. Social 5:30; Dinner 6:15. Peoples Gas Auditorium. 7:45. Loop Meeting. "Automatic Arc Welding." A panel meeting moderated by Amel Meyer, American Oil Co.

MILWAUKEE Section. "Vertomatic and Electroslag Welding," W. H. Wooding, Arcos Corp.

OCTOBER 24

SANTA CLARA VALLEY Section. Sabella's Restaurant, Sunnyvale, Calif. 7:00 P.M. "Silver Brazing Filler Metals," Stanley Cross, American Platinum & Silver Div., Engelhard Industries, Inc.

OCTOBER 31

PITTSBURGH Section. Educational Course "Welding Metallurgy." Lecture 5.

NOVEMBER 1

SUSQUEHANNA VALLEY Section. Foothills Manor; Shickshinny, Penna. Dinner 6:30. Panel Discussion on "Limitations of Welding Processes": John Mikulak, Worthington Corp., Wm. Apblett, Foster Wheeler Corp. Third member to be announced.

NOVEMBER 2

NORTHERN NEW YORK Section. Hot Shoppes, Route 9, Albany, N. Y. "Recent Discoveries from Welding Research," W. F. Savage, Rensselaer Polytechnic Institute.

NOVEMBER 7

AUSTIN Division. "Design Factors in Welded Connections."

PITTSBURGH Section. Educational Course "Welding Metallurgy." Lecture 6.

NOVEMBER 9

CHICAGO Section. Calumet Meeting. Social 5:30. Dinner 6:15. Meeting 7:45 P.M. at Jockey Club, East Chicago. "Hard Surfacing," Howard Avery, American Manganese Steel Co.

KANSAS CITY Section. "Low-Hydrogen Rods," Don Hilton, Harnischfeger Corp.

PUGET SOUND Section. Field trip to Atomic Energy Works, Hanford, Wash.

RICHMOND Section. Richmond, Va. Speaker A. F. Chouinard, President, AWS and Director Research and Development, NCG.

ST. LOUIS Section. Ruggeri's Restaurant. "The Welding Engineer—Who Is He—Can We Justify His Existence?" Prof. Roy B. McCauley, Ohio State University.

NOVEMBER 13

BOSTON Section. "Argon-Shielded A.C. Metal-Arc Welding," C. R. Sibley, Airco.

NOVEMBER 14

COLORADO Section. Annual Ladies Night.

PITTSBURGH Section. Educational Course "Welding Metallurgy." Lecture 7.

TULSA Section. "Technical Inspection of Welds," Leo Coombs, Field Inspection Service.

WESTERN MASSACHUSETTS Section. Oaks Inn, Springfield, Mass. Dinner 6:30. Meeting 7:45 P.M.

NOVEMBER 15

HOUSTON Section. "Stainless Steels," George Linnert, Armco Steel Corp.

PITTSBURGH Section. Webster Hall Hotel. Coffee Talk "Professionalism." "Flame Straightening," J. C. Stitt, R. C. Mahon Co.

TOLEDO Section. Toledo Yacht Club. Dinner 6:30. Meeting 7:45 P.M. High School Night. "Advantages in Becoming a Welding Engineer," Roy McCauley, Ohio State University.

NOVEMBER 16

CHICAGO Section. Northwest Meeting. Social 5:30; Dinner 6:15; Meeting 7:45 P.M. at Henrici's in the O'Hare Inn. "The Impact of Cryogenics on Industry," W. T. Dellinger, National Cylinder Gas.

LOS ANGELES Section. Rodger Young Auditorium, 6:30 P.M. "Welding Aluminum," Bob Baysinger, Kaiser Aluminum.

PEORIA Section. Vonachen's Junction. Dinner 6:30. Meeting 8:00 P.M. "Hard Surfacing," Leonard Sadowski, Stoody Co.

SABINE Section. "Stainless Steels," George Linnert, Armco Steel Corp.

STARK CENTRAL Section. Reeves Hotel, New Philadelphia, Ohio.

NOVEMBER 17

MILWAUKEE Section. "New Fields for Resistance Welding," A. W. Schueler, Precision Welder & Flexopress Corp.

NOVEMBER 18

HARTFORD Section. Dinner Dance.

NOVEMBER 21

J.A.K. Section. Joliet, Ill. Joint meeting with ASTME and QCS. "Productivity."

NEW JERSEY Section. Essex House, Newark, N. J. Dinner 6:30; Meeting 8:00 P.M.

OLEAN-BRADFORD Section. Castle Restaurant, Route 17, Olean, N. Y. Dinner 7:00 P.M. Meeting 8:00 P.M. "Automatic and Semi-Automatic Welding," Jerry Hinkel, Lincoln Electric Co.

PITTSBURGH Section. Educational Course "Welding Metallurgy." Lecture 8.

NOVEMBER 28

PITTSBURGH Section. Educational Course "Welding Metallurgy." Lecture 9.

Editor's Note: Notices for January 1962 meetings must reach JOURNAL office prior to October 20th so that they may be published in the December Calendar. Give full information concerning time, place, topic and speaker for each meeting.

Symbols for Welding

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ROCHESTER "PARTY HOUSE" . . .

Some of the 105 members and guests who thoroughly enjoyed themselves at the annual dinner dance of the Rochester Section on April 15

Virginia

SOCIAL

Roanoke—The first annual social of the newly chartered *Southwestern Virginia* Section was held on July 18th at Yearly Haven. Twenty-six members attended the informal meeting, enjoyed buffet dinner and discussed plans for the coming fall-winter activities.

Officers of the new Section are: Chairman, H. G. Humphrey; 1st Vice-Chairman, C. H. Sheehan; 2nd Vice-Chairman, E. J. Hughes; Secretary, R. G. Lochner; Treasurer, R. L. Rule; Directors, J. H. Baker, W. K. Cundiff, S. Oliver and W. McLaren.

Wisconsin

NEW OFFICERS

Milwaukee—The new officers and Executive Committee for the *Milwaukee* Section are as follows: Chairman, L. E. Bluhm; 1st Vice-Chairman, D. C. Smith; 2nd Vice-Chairman, Yost T. Smith; Secretary, M. W. Zimmermann; Treasurer, Cedric A. Wells; Nominating Committee, J. S. McKeighan; Publicity, Robert Manning; Membership, W. G. Rinehart; Technical Representative, H. L. Schneider; Educational Representative, F. J. Harencki; Educational Program, D. E. Cox.

An interesting and active 1961–62 season has been planned by the Board. A highlight will be the Educational Program planned by Chairman Cox, wherein the subject of "High - Strength, Low - Alloy Steels" will be covered from the forming, layout, through welding and inspection.

CHANGE OF RESIDENCE ADDRESS OR COMPANY AFFILIATION

DATE .....

NAME ..... (LAST / FIRST / MIDDLE)

RESIDENCE ADDRESS ..... (STREET)

..... (CITY / ZONE / STATE)

COMPANY NAME .....

COMPANY ADDRESS ..... (STREET)

..... (CITY / ZONE / STATE)

Title of position held .....

Mail should be sent to my residence ☐ company ☐ (check one)

I wish to be affiliated with ..... the AWS Section

NOTE: To assure that your copy of the Welding Journal is mailed to your new address, this change of address notice must be received at American Welding Society, 345 East 47th Street, New York 18, N. Y., no later than the 25th of the month previous to issue mailing.

New Members

EFFECTIVE AUGUST 1, 1961

MEMBERSHIP CLASSIFICATION

A—Sustaining Member
B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Member

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	204
Members	6,515
Associate Members	5,701
Students	364
Honorary Members	11
Life Members	32
Total	12,827

CANADA
Graham, James H. (B)
Lambton, Robert Eric (B)
Monks, Gordon E. (B)

CAROLINA
Clark, Robert S. (B)

CHICAGO
Van Blaracom, James W. (C)

CLEVELAND
Miller, Alex S. (D)
Thompson, Daniel (C)

DAYTON
Bartlow, Robert (B)

DETROIT
Lowen, Leslie (C)

FOX VALLEY
Hinkley, Howard W. (B)

HAWAII
Carl, John W. (B)
Chun, Thomas T. W. (B)
Kubota, Katsuro (C)
Larson, Kenneth (B)
Obara, Wilbur (B)

HOUSTON
Voight, George H. (B)

INDIANA
Nestor, Ontario H. (B)

LONG BEACH
Shradeja, Joseph P. (C)

LONG ISLAND
Arlis, Anthony T. (B)

LOS ANGELES
Steinmetz, Paul C. (C)

MICHIANA
Stanton, Vincent A., Jr. (B)

MILWAUKEE
Fredelake, Louis W. (C)

NEW JERSEY
Golding, Jack (B)
Shah, Chandrakant K. (C)
Van Der Ploog, Daniel (B)

NIAGARA FRONTIER
Purdy, F. J. (A)

NORTH TEXAS
Ruyle, Melvin E. (C)

NORTHWESTERN PA.
Jones, Thomas L. (B)

OLEAN BRADFORD
Campbell, Richard A. (D)
Dreher, Henry J. (C)
Weinman, Marshall (C)

ORANGE COUNTY
Phillips, Wendell B., Jr. (B)

PHILADELPHIA
Urban, Joseph R. (B)

PITTSBURGH
Archer, Clark (B)
Brill, Frederick W. (C)
Mattern, Robert E. (C)
Rosenthal, James W. (C)

PUGET SOUND
Pasley, Dallas H. (B)

RICHMOND
Black, James K. (C)
Booker, William F., Jr. (B)

SAGINAW VALLEY
Hembree, James D. (C)

SANTA CLARA VALLEY
Hensley, William E. (B)

SYRACUSE
Spiegel, Leonard (B)

YORK-CENTRAL PA.
Rutledge, Carroll N. (C)

MEMBERS NOT IN SECTIONS
Bell, Gerald Robert (B)
Cantrill, Arthur (B)
Edwards, Walter (B)
Trehan, C. L. (B)

Reclassifications During August 1961

OLEAN-BRADFORD
Thompson, Harold (C to B)

SAN ANTONIO
Valenta, Joe I. (C to B)

SUSQUEHANNA VALLEY
Diehl, Charles (C to B)

DOMESTIC SOCIETY
Brown, Reubin Henry (C to B)

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NEWS of the industry

NCG Distributes American Optical Safety Products

A new line of personal protection equipment for welding and cutting is being marketed by the National Cylinder Gas Division of Chemetron Corp. which has become the only national distributor for the Safety Products Division of American Optical Co., it was jointly announced.

NCG dealers throughout the country will stock goggles, face shields, helmets, filter lenses, hats, caps, and other protective equipment supplied exclusively by American Optical, a leader in the field for more than 50 years, the announcement said.

Products new to the NCG line as a result of this arrangement include a dust respirator, a special helmet lens for inert arc welding and softside chipping goggles. American Optical has developed a new line of face shields to meet the needs of the welding industry.

NCG is a leading producer and distributor of a complete line of welding and flame cutting equipment, accessories and industrial gases.

New Firm to Produce Welding Supplies

It was announced today that Welding Products Corp., located at 17 Bertel Avenue in Mt. Vernon, N. Y., has been formed in the interests of the welding supply distribution field. The firm will manufacture and distribute welding cable, welding hose, safety equipment and related items, throughout the U. S. Stan Schumann is national sales manager.

Resistance Welding Shipments Up

Members of the Resistance Welder Manufacturers Association in their latest statistical review reported shipments of more than $2\frac{1}{2}$ million of equipment during July. This was the fifth consecutive month that shipments have been substantially in excess of $2 million.

For the first seven months of 1961, shipments total almost $17 million, which is just 6% under the comparable 1960 period. With each month, the 1961 year-to-date totals have been slowly closing the gap between comparable 1960 statistics.

New orders received during July were the highest for any month thus far in the current year. July also was the fourth month during 1961 in which the Members of the Association received more than $2 million in new business.

Backlogs at the end of July were reported in excess of $7 million, down somewhat from the early part of the year.

Welding Workshop at Trenton State College

Trenton State College with the cooperation of the State Department of Education, has for the last three summers, offered a summer welding workshop to help reestablish competent teaching of welding in the industrial arts laboratories located throughout the state of New Jersey.

This year, the college, with the cooperation of Hobart Brothers Co., arc welding equipment manufacturers of Troy, Ohio and Air Reduction Co., of New York, presented to industrial arts teachers the latest techniques in arc and oxyacetylene welding. Twenty one high school industrial arts teachers throughout the state of New Jersey, spent one

CONTRAST BETWEEN ERAS

Scene during 1893 in the lower Manhattan offices of Handy & Harman when the company was primarily a financial house dealing in gold bullion, specie and bonds

Almost 70 years later in mid-1961, Handy Harman moved uptown in Manhattan to new quarters at 850 Third Avenue where this is the sight greeting visitors after getting off elevators

This is a P&H engine-driven welder.
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All sizes. All good. All dependable.
Nothing fantastic about how they work.
They just weld good like they should.
Know why?

We build 'em as though we were going to buy'em ourselves!

Know a better guarantee of quality?

HARNISCHFEGER
Milwaukee 46, Wisconsin
P&H
WELDING PRODUCTS DIVISION

week of three hour evening sessions on June 12th and ended with two weeks of eight hour workshop sessions on June 30th. Each teacher had to construct at least two school shop projects that could be made by his students next fall in their classes. Those who participated and met all requirements received three credits and a certificate of competence from the State Department of Education. New Jersey teachers are required to have this certificate to teach welding.

Willson Names Distributor

The Richardson Supply Co., Kansas City, Mo., has been appointed the franchise distributor for Willson Products Div., Ray-O-Vac Co., Reading, Va., in the Kansas City area. Willson manufactures a full-line of more than 300 different safety products for personal safety: head, eye, respirator and hearing.

Richardson Supply will handle safety clothing, fire equipment and other lines as well as Willson safety glasses, goggles, hard hats, earmuff type hearing protection, welding goggles and helmets, respirators and gas masks.

Lincoln Opens Combination Office-Warehouse

A combination office-warehouse has been constructed in St. Louis, Mo. by The Lincoln Electric Co. of Cleveland, Ohio. The pre-fabricated, welded steel structure will perform three basic functions to facilitate the sale and distribution of Lincoln's complete line of welding equipment and supplies in the St. Louis district. Housing office, demonstration, and warehouse activities, the structure provides space for rapid processing of district orders and correspondence, stocking material to insure quick delivery, and introducing and demonstrating the practical application of new or existing products to local fabricators.

The 40 by 122 ft building has 3280 sq ft of floor area for warehousing upwards of $^1/_2$ of a million pounds of welding electrode and 100 welding machines and 3 phase AC squirrel cage induction motors. A protected 20 by 20 ft dock equipped with a hydraulically adjustable unloading ramp aids efficient movement of shipments into and out of the warehouse.

The St. Louis unit is the second office-warehouse building in a program to put this type of distribution facility in important industrial areas throughout the country.

Southern Oxygen to Distribute GE Electrodes

The appointment of the Southern Oxygen Co. as wholesaler and warehouse outlet for General Electric tungsten electrodes was announced recently.

Southern Oxygen, located at 2900 52nd St., Bladensburg, Md., will market the entire General Electric tungsten electrode line along the east coast. Its territory includes Florida, Georgia, South Carolina, North Carolina, Virginia, District of Columbia, Maryland, Delaware, New Jersey and the eastern parts of Tennessee, West Virginia and Pennsylvania.

Eutectic Sponsors Welding Clubs

Organization of the National Eutectic Maintenance Weldors' Club and sponsorship of Regional Eutectic Maintenance Weldors' Clubs have been officially announced by the Eutectic Welding Alloys Corp., Flushing, N. Y.

Eutectic's Chairman of the Board, Rene D. Wasserman, is the founder of the new organization. Wasserman discerned the need for a membership activity which would serve the "weldor" and those concerned with welding in a practical nontechnical way. Professional technical societies provide excellent engineering and metallurgical services and education through their regional meetings and publications. However, practical weldors, particularly those in the maintenance field, have additional and specialized needs which can be satisfied only through activities permitting talks in nontechnical language on new techniques and materials, on-the-spot demonstrations, audience participation through try-it-yourself facilities, and opportunities to exchange information with other weldors; all in regularly scheduled get-togethers.

Within this area Mr. Wasserman and Leonard C. Barr, Eutectic's President, believe that their company's institution of Weldors' Clubs can render a distinctive and valuable service to weldors and industry concerned with the joining of metals.

COMING EVENTS

A Calendar of Welding Activity

AWS

April 9–13, 1962. 43rd Annual Meeting and Exposition, Cleveland, Ohio

AIME

Oct. 24. The Metallurgical Society's annual Fall Meeting, Pick-Fort Shelby Hotel, Detroit, Mich.

ASM

Oct. 23–27. Detroit Metal Show (43rd National Metal Congress and Exposition), Cobo Hall, Detroit, Mich.

ASME

Oct. 17–18. Materials Handling Conference, Pick Nicolette Hotel, Minneapolis, Minn.

Oct. 17–19. Lubrication Conference, Morrison Hotel, Chicago, Ill.

ASQC

Oct. 19–20. 16th Midwest Conference, Chase-Park Plaza Hotel, St. Louis, Mo.

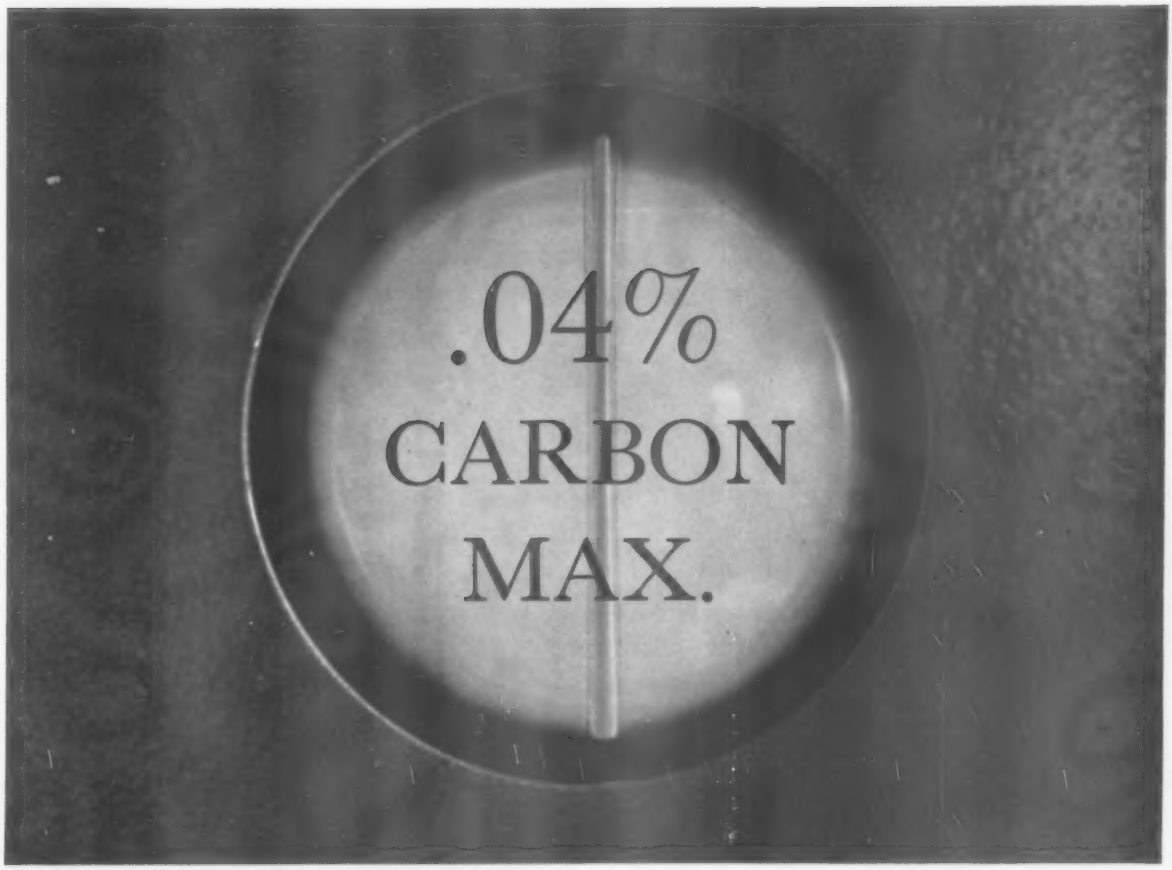
NWSA

Oct. 9–10. West Central Zone Meeting, Pick-Niccollet, Minneapolis, Minn.

Oct. 12–13. Western Zone Meeting, Riviera Hotel, Las Vegas, Nev.

* * * *

Oct. 16–20. National Safety Congress and Annual National Safety Council Convention, Chicago, Ill.



Carbon content is critical to the success of the stainless steel fabricator and super critical where the extra low carbon grades of electrodes are involved.

Accurate determination of carbon content in Arcaloy stainless steel electrodes is one of the essential steps in the quality control program at Alloy Rods Company. A staff of chemists and metallurgists, using the most modern equipment and processes and following precise standards for quality, analyze weld deposits of every type and every lot of Arcaloy electrodes. The high degree of dependability long associated with Arcaloy electrodes is characteristic of all Alloy Rods' electrodes and wires . . . for stainless steel—low alloy high tensile steels—non-ferrous alloys—hard surfacing and tool steel alloys.

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For details, circle No. 5 on Reader Information Card

Marquette Purchases Canadian Manufacturing Firm

H. J. Lange, President of Marquette Corporation, (Minneapolis) recently announced that Marquette has purchased the Regent Equipment Manufacturing Co., Ltd., Rexdale (Toronto) Canada.

The Regent Equipment Manufacturing Co., Ltd., is a manufacturer of electric arc welders, battery chargers, testers, and motor tune-up equipment in Canada. It was founded in 1927 and built the first arc welders manufactured in Canada.

The purchase was effected through an exchange of stock between Marquette Corporation and the owners of Regent Equipment Manufacturing Co., Ltd. The company will operate under its present name, as a wholly owned subsidiary of Marquette Corp.

Mr. Ralph Gruber, former president of Regent Equipment Manufacturing Co., Ltd., becomes executive vice president. Mr. William Gruber has been named vice president and works manager. Mr. C. W. Kirkpatrick continues as vice president and general sales manager.

In addition to manufacturing the present Regent line, Marquette products will be manufactured as soon as is practical in the new modern plant constructed about 2 years ago.

This acquisition provides Marquette the Canadian facilities to develop the growing needs for its various products throughout Canada and to better serve its distributors in the Dominion.

International Congress on Experimental Mechanics

The First International Congress on Experimental Mechanics to be conducted by the Society for Experimental Stress Analysis will be held at the Hotel New Yorker, New York City, on Nov. 1–3, 1961.

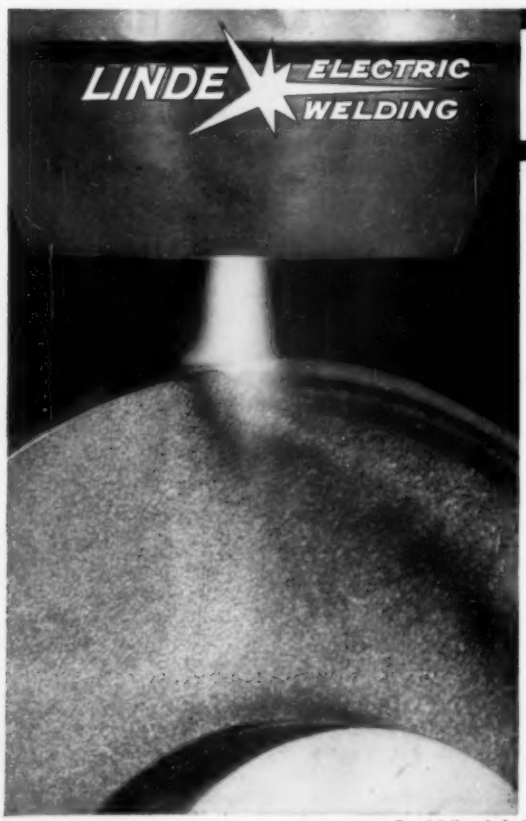
A series of five morning and afternoon technical sessions will be held during which 22 papers will be presented by authors from this country and abroad. A sixth session will comprise the William M. Murray Lecture, this year to be given by Egon Orowan, George Westinghouse, professor of Mechanical Engineering at Massachusetts Institute of Technology. Professor Orowan will discuss recent findings on the structure of the cold-worked crystal.

Authors from more than a half dozen countries abroad will travel to this country to present their papers at the Congress. While major emphasis is on various phases of experimental stress analysis, other areas of experimental mechanics will be treated.

The Congress will also feature an exposition of the latest equipment and instrumentation used in the field. Displays by manufacturing organizations, educational institutions and governmental agencies will occupy the mezzanine exhibit area of the hotel.

Principal speaker at the banquet will by Emile Jossis Lapian, Indonesian Minister to the United Nations. A civil engineering graduate from the University of Technology, Bandung, Indonesia, Mr. Lapian has addressed other engineering groups since his arrival here in 1959.

Other events will include two simultaneous educational lectures; one on basic strain-gage theory and technique, and the other on some aspects of advanced techniques. An interesting ladies program will offer visits to historic and modern places of note including the United Nations and current fashion shows.



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- Deposits as narrow as 1/8-in., as wide as 1 in. or more.
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UNION CARBIDE

For details, circle No. 14 on Reader Information Card

Mobile Welding Repair Shop

One of the first mobile equipment repair shops in the welding industry has just been placed in service by Garden State Welding Supply Co.—local authorized Air Reduction Sales

Co. distributor located at 431 Danforth Ave., Jersey City, N. J. According to Garden State's president Jack Howe, the fully equipped machine shop housed in a compact, half-ton truck will help reduce costly production downtime due to equipment breakdowns by making repairs at the customer location.

NCG Names 7 Representatives

Appointment of seven new dealer representatives in six districts has been announced by the National Cylinder Gas Division of Chemetron Corp. The men will develop dealer and distributor sales at their respective locations.

Names were G. P. Zielke and R. J. Eisler, Chicago district; N. P. D'Alessandro Jr., Boston district; H. B. Stormer, Buffalo district; F. J. Gordon, Cleveland district; K. W. Clemen, Philadelphia district; and R. C. Weiss, St. Paul district.

The appointments bring to 12 the number of dealer representatives now operating in NCG districts under an expanded dealer relations program.

English Firm Establishes U.S. Division

North American Division of Triangle Products, Ltd., Hyde, England, was established in March 1961 in Neptune, N. J., in response to an increased demand for the company's transformer welders, according to Ernest R. Hartley, president of the Division.

Numerous distributors have been set up throughout the United States and Canada: A. B. S. C. O., Inc., 2202 S. Garfield Ave., Los Angeles, Calif.; I. W. E. C. O., 3815 Gulf Freeway, Houston, Tex.; Middlesex Welding Supplies, 705 Evergreen Ave., Bradley Beach, N. J.; Mineweld Co., 4565 De Tonty St., St. Louis, Mo.; Virginia Welding, 900 McDonnough St., Richmond, Va.; Welding Gas & Equipment Co., 7425 E. Davison Ave., Detroit 12, Mich.; Welders Supply Co., Wheeler Rd., Burlington, Mass.; and Europa Importing Co., 2200 Kingston Rd., Toronto, Canada.

Triangle Products manufactures various spot welders and a Monoflex unit which has many applications in the automobile body repair field.

Instrument-Automation Conference

With the theme "Reliable Information—From Undersea to Outer Space," the 16th Annual Instrument-Automation Conference & Exhibit of the Instrument Society of America was held in Los Angeles, Sept. 11–15, 1961. More than 275 papers and presentations were given during 72 technical sessions on some 30 different subjects, making this the largest conference and exhibit yet held by the Society. More than 25,000 scientists, engineers, educators and technicians, from all parts of North America, as well as from Europe and the Far East, were in attendance.

The annual meeting of the Society, with election of officers, was held on Sept. 12th, in The Biltmore Hotel, the Conference Headquarters. On the same day the Society's Honors and Awards were conferred at a special luncheon.

The Exhibit, featuring several millions of dollars worth of the latest developments in instrumentation, systems and concepts, by more than 300 of the nation's leading manufacturers, was held in the new Memorial Sports Arena during the five days of the Conference.

Materials Conference Scheduled

A technical conference covering recent research in the field of materials science will be held December 18th and 19th at Rensselaer Polytechnic Institute.

This meeting will be sponsored jointly by the Institute and the Watervliet Arsenal with the cooperation of the Advanced Research Projects Agency, the Atomic Energy Commission, the National Aeronautics and Space Administration, and the U. S. Army.

The program will include the presentation of original research papers in the following areas of interest: mechanics of materials, solid state

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physics, physical metallurgy, and the physicochemical properties of materials. In addition, a summary and review of the status of materials research programs supported by most of the cooperating federal agencies will be given. This conference will provide an excellent opportunity for participants to exchange viewpoints and to keep abreast of recent advances in their related fields.

Papers representing an important contribution in the area of materials research and involving recent work not reported elsewhere are desired. Abstracts of such papers should be submitted to Dr. M. J. Hordon, Research and Engineering Division, Watervliet Arsenal, Watervliet, N. Y., prior to October 1st for consideration. Notification of acceptance will be made by October 23rd.

In order to facilitate evaluation, submitted abstracts should be a minimum of 500 words although submission of the entire paper is encouraged whenever possible. It is planned to incorporate the abstracts of accepted papers in the Proceedings of the conference.

Beckman Acquires Offner

Beckman Instruments, Inc., recently announced that the company has completed acquisition of the assets and operations of Offner Electronics, Inc., for 58,823 shares of Beckman common stock.

Offner of Schiller Park, Ill., a suburb of Chicago, will become a division of Beckman. No changes are contemplated in Offner personnel.

Dr. Arnold O. Beckman, president, said that principal Offner products, a direct-writing oscillograph, electroencephalographs, and direct-current amplifiers, will add significantly to Beckman's lines of industrial, medical and space instrumentation.

The Illinois firm, a manufacturer of industrial and medical electronic instrumentation, was founded in 1939 by Dr. Franklin F. Offner who will be technical director of the Offner Division. The company recorded sales of $2,922,000 and earnings of $368,000 for the fiscal year which ended last December 31st.

Four Install NCG Oxygen Converters

Four welding suppliers have installed liquid oxygen converter units to ensure a constant supply for customers by filling cylinders with gas at high pressure from a supply of easily-stored low-pressure liquid oxygen.

The distributors of the National Cylinder Gas Division, Chemetron Corp., Chicago, Ill., are: Midstate Welding Supplies, Flora, Ill.; Oxygen Service Co., Inc., 970 Scott St., Kansas City, Ka.; Industrial Oxygen and Supply Co., 1010 Levee St., Dallas, Tex.; and Tri-State Oxygen Corp., 331 Viola St., Camden, N. J.

American Brazing Alloys Wins Army Contract

Award of a contract from the Army Ordnance Corps has been given to American Brazing Alloys Corp. Pelham, N. Y. The contract calls for the supply of silver solder to Picatinny arsenal in New Jersey.

The firm is a producer of brazing alloys including low fuming bronze, nickel silver, silver solder, phosphorus copper and phosphorus silver alloys.

Welding Workshop Courses for Supervisory Personnel

Four short workshop courses designed to upgrade the ability of key personnel to direct, control and evaluate fusion welding operations will again be conducted this fall by Hobart Brothers Technical School, Troy, Ohio.

Each course is for a five day period. Text and a complete package of reference material will be furnished. Following is a schedule of the course that will be made available.

Arc Welding Inspection and Quality Control—October 9–13. This course outline covers the importance for quality welding in manufacturing and construction.

Welding Fundamentals for Supervisors and Engineers—November 13–17. Arc welding procedures, principles and economical applications will be discussed and demonstrated.

Automatic Welding for Management—November 27–December 1. This will consist of a complete explanation of the requirements, equipment-wise, for each process and an explanation of the electrical requirements.

Gas Shielded-Arc Welding Processes—December 4–8. This course covers a thorough explanation of the tungsten-inert-gas arc welding process, its operation and its applications.

Registration fee for each five-day course is $50 for each man. Registration Bulletin DM-194 includes a full description and schedule of classes. Reservations may be made by wire, letter or telephone to the School Director, Hobart Brothers Technical School, Troy, Ohio.

NCG to Introduce Track Inspection Lab

National Cylinder Gas Div. of Chemetron Corp., Chicago, Ill., recently obtained exclusive rights in the United States and Canada to products of Alfred J. Amsler & Co., Schaffhausen, Switzerland, builder of precision testing equipment.

First of the products to be introduced in this country will be the

NCG-Amsler Track Inspection Car, a mobile laboratory for determining the condition of railroad track.

It simultaneously measures gage (dimension between rails), cross level (height of a rail in relation to the other), gradient (rate of ascent and descent), curvature, twist (height of a car wheel in relation to a plane formed by three other wheels), and distance the car travels. All of the track information is continuously recorded in U. S. measurement standards on a single roll of paper.

NCG will also market a small, manually propelled Track Inspection Unit, easily lifted onto and off track, designed for local measurement work.

Supplier Changes Name

Hendersonville Welding & Supply Co. has changed its name to "Andy-Oxy-Co."

"Our new name is shorter, easier to say and remember, and it sounds friendlier," said W. S. Anderson, owner and manager of the firm located at 1521 Asheville highway, Hendersonville.

Andy-Oxy-Co. is a dealer for NCG oxygen, acetylene and a complete line of welding equipment and supplies, and is a distributor of fire extinguishers.

Aluminum Strength Increase Shown in Cryogenics Studies

Previously unavailable data on the strength properties of the 5000-series of aluminum-magnesium alloys were reported at a session of the Cryogenic Engineering Conference here today. The data confirm that these alloys have distinct advantages for use at the ultralow temperatures of liquid oxygen and hydrogen.

A report on experiments at the Battelle Memorial Institute, Columbus, Ohio, sponsored by The Aluminum Association, noted: "In general, the data show that the tensile strengths of all of the aluminum alloys in the welded and unwelded conditions increase as the temperature is lowered from room temperatures to −423° F . . . They do not, for example, reveal a transition from ductile-to-brittle behavior as the test temperature is lowered."

The report presents the first comprehensive data ever prepared on aluminum plate in this alloy series at the temperature of liquid hydrogen. One of the alloys, 5083, has been used for two 35-foot liquid-hydrogen tanks recently completed by Douglas Aircraft Co. at its Sacramento, Calif., facility.

Also studied was one stainless steel alloy, 304 plate. Separate investigations were made on welded and unwelded, notched and unnotched samples. One conclusion was: "In general, the yield strength-to-density ratios of the 5000-series aluminum alloys, both welded and unwelded, were higher than those of the Type 304 stainless steel at room and cryogenic temperatures."

Linde Increases Armco Oxygen Supply

A new 140 ton-per-day on-site plant is now supplying oxygen to the Armco Steel Corp., according to a recent announcement from the Linde Co., Div. of Union Carbide Corp.

This is the second plant built by Linde at Middletown, Ohio, since 1959. Bulk of the oxygen supply will be used in Armco's open-hearth furnaces. The new plant will also provide oxygen for such mill operations as welding, heating, cutting and scarfing.

National Metal Trades Association Convention

The National Metal Trades Association will hold its annual (1961, 62nd Year) Convention at the Commodore Hotel in New York City during the four days of October 29th through November 1st, 1961, according to an announcement by Paul W. Christensen, Jr., its president. Mr. Christensen is also president of Cincinnati Gear Company, Cincinnati, Ohio.

The business of the Convention will be seminars on executive solutions to management problems of policy making in the fields of industrial relations, manufacturing, sales and business financing.

Capt. Eddie Rickenbacker, Eastern Airlines' Board Chairman, will be the annual banquet's keynote speaker. Other leading business and public figures will lead discussions on domestic and world problems relating to the Convention's primary purposes.

New Welding Development Lab

General American Transportation Corp. is opening a new welding development laboratory at their Plant No. 3, East Chicago, Ind. This laboratory will be headed by Mr. O. H. (Ollie) Kuhlke, who will be located in the Chicago district as the Director of Welding Research and Development for General American.

Geoscience Leases Additional Space

Geoscience Instruments Corp. is moving to substantially larger facilities at 110 Beekman St., New York 38, N. Y. The new headquarters will accommodate Geoscience's new Materials Processing Laboratory. The premises are divided into clean rooms in which the company will fabricate and finish metals, ceramics, and exotic materials. The laboratory is also equipped to do research work on metals and ceramics. The company specializes in the materials, equipment, and techniques required in critical surface preparation work, especially polishing.

Dorcon Formed to Manufacture Tanks, Vessels

Dorcon Inc., a wholly-owned subsidiary of Dorr-Oliver Inc., Stamford, Conn., is being formed to engage in the design, manufacture, fabrication and field erection of metal tanks, water and chemical storage facilities, and process and reaction vessels.

Officers of the new company will be president Alex Fino, treasurer K. Earl Abel, and secretary John W. Swick. Administrative and engineering offices will be at Warren, Pa., and sales headquarters in Pittsburgh, Pa., with Max G. Walker as sales manager.

The addition of Dorcon to the Dorr-Oliver group of companies will provide a specialized organization to engineer and erect plate steel vessels required in connnection with such Dorr-Oliver equipment as thickeners, clarifiers, and reactors, and with Dorr-Oliver process and plant engineering operations. In addition, the new company will manufacture, erect, and market a complete line of steel plate, alloy and aluminum tanks and vessels, such as elevated water tanks, petroleum storage tanks, digesters and reactors. The officers and engineering and supervisory staff are all closely familiar with this field, with many years of experience in design and erection of such vessels.

Alex Fino

Alex F. Fino AWS, president of the new company, is well-known in petroleum, petrochemical and related technical circles. He has designed and developed such products as seals for floating roofs, variable vapor-space devices, and related products for the oil industry, and has been granted 24 patents for these developments in the United States and abroad.

Electronic Manufacturing Methods Advance

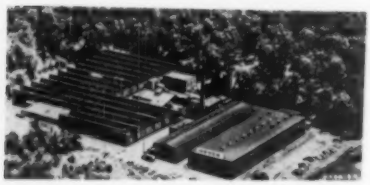
A new method of electronic timer production, resulting in longer life, greater reliability and mechanical strength, increased resistance to shock and vibration, and lighter and smaller packages has been announced by The A. W. Haydon Co. of Calif., Culver City, Calif.

Developed jointly by Massachusetts Institute of Technology, Space Technology Labs and The A. W. Haydon Co., the new method, known as welded module technique, is claimed to be one of the most significant advances in the state of timer art since World War II, according to the company.

The new technique utilizes photographic films which are prepared to exact dimension from engineering layouts showing the location and position of each component. A sandwich of a pair of these mylar film wafers is made, with the electronic components inserted into their marked position side by side in order to utilize their mutual supporting strengths as well as to eliminate the need for any supporting structure such as clips.

Marquette Purchases Heyer Industries

The Marquette Corp., Minn., has announced the purchase of Heyer Industries, Inc., Belleville, N. J., Heyer Products Co., Heyer Service Co., and several affiliated companies.



The Heyer product line includes a wide range of motor tune-up and battery service equipment.

Included in the purchase are Heyer's modern 150,000 sq ft plant at Bangor, Pa., and a new administration, engineering and research center.

Course in Nondestructive Testing

A gift of highly technical nondestructive testing equipment has been presented to Sacramento State College by Sperry Products Co., Danbury, Conn., a division of Howe Sound Co. (NYSE), metals manufacturer. This gift, plus additional equipment purchased from Sperry and some already owned by the school, gives Sacramento State the broadest, most comprehensive nondestructive testing training and engineering facilities of any school in the country.

The formal presentation was made by Philip J. Parker, Sperry sales manager, to F. Blair Mayne, Executive Dean of Sacramento State College, at ceremonies conducted in the Division of Engineering headed by Edwin B. Weinberg, chairman of the Engineering Div., and Dr. George N. Beaumariage, Jr., faculty member responsible for research and development for the Engineering Div. and director of the Institute of Nondestructive Testing. Robert Oliver, national president of the Society for Nondestructive Testing, participated in the ceremonies and Douglas Ballard of Sandia Corp. gave the opening speech.

Two new buildings have been constructed specifically to house this relatively new science—one building devoted entirely to radiography and the other to be used for all other nondestructive testing facilities—ultrasonic, magnetic particle, penetrants, eddy current, and optical testing.

Dr. Beaumariage said the college now plans an integrated facility for nondestructive testing. The college hopes to develop a Bachelor of Science degree in Material Science Engineering and offers all requirements for a Bachelor of Science in Mechanical Engineering.

The Sperry gift includes the latest in ultrasonic reflectoscopes and accessories, ultrasonic positioning equipment for immersion testing, large Sonoflux magnetic particle testing machine with black light and portable magnetic particle testing units and accessories.

Longest Nitrogen Pipeline

The longest nitrogen pipeline in the United States will soon bring high purity nitrogen in large quantities to plants in the rapidly expanding Delaware Valley chemical complex. Air Reduction Co., Inc., will pipe more than 100 tons of nitrogen per day to du Pont and Shell Chemical Co. plants at the ends of the T-shaped line.

The pipeline will be more than 22 miles long and will originate at Airco's $6\frac{1}{2}$ million air separation plant now under construction on a 9-acre site at Claymont, Del., and cross the Delaware River into New Jersey. One leg will go 12 miles north to Shell Chemical's polypropylene plant at Woodbury and the other 10 miles south to du Pont's Chambers Works at Deepwater Point. In the future, taps are planned at other points along its length to serve additional customers. Air Reduction has acquired 34 acres in Oldmans Township, N. J., for future expansion of its industrial gas producing facilities.

Another pipeline, this one of stainless steel, will deliver Airco oxygen to customers in New Jersey. The oxygen and nitrogen pipelines are two of eight being constructed by the SunOlin Chemical Company to deliver raw materials from Delaware and Pennsylvania to chemical plants on the New Jersey side of the river.

New Homopolar Generator Discussed

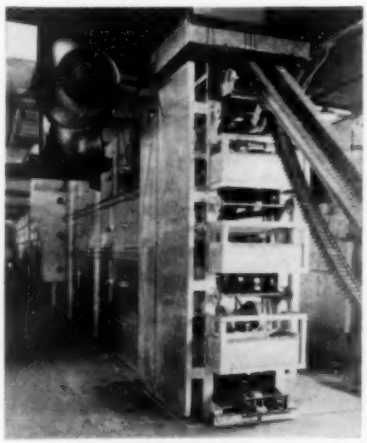
Homopolar direct current generators, discarded in the past because of their very low voltage and efficiency, have become quite popular because of present demands for very high currents at very low voltage. Such machines have been built to supply 250,000 to 300,000 amp to electromagnetic pumps which are used to circulate liquid metals within nuclear reactors and to supply high currents for welding apparatus and larger magnets such as can be found in synchrocyclotrons.

A rotating machinery symposium at the Summer General Meeting of the American Institute of Electrical Engineers at Cornell University June 18–23, was told that a new and efficient type of generator has been designed, with the principal advantage of supplying current and voltage equal to an ordinary homopolar generator of twice the size.

The new kind of generator has no stator cylinder and the rotor is made up of two cylinders rotating in opposite directions, one known as the main cylinder and the other as the armature reaction compensating cylinder. When the two cylinders are properly connected and rotated in one standard field flux, the output power is nearly doubled and the voltage is nearly twice as large as the voltage from an ordinary machine of the same size with a fixed compensating cylinder. Because the compensating cylinder rotates in the same flux as the main cylinder, the overall effective length of the air gap is increased. This requires an enlargement in dimensions over those of the standard compensating cylinder machines.

The homopolar generator, described by A. K. Das Gupta, of the Illinois Institute of Technology, was said to be small compared with any other machine of the same capacity.

Electrode Baking Oven



One of the largest electrode baking ovens in the world, designed and built to McKay specifications, this 50-ton unit has been installed at the York, Pa., plant of the McKay Co. as part of their continuing program of expansion. The new oven doubles existing capacity to produce low hydrogen electrodes. Literally miles of electrodes can be produced each hour.

PERSONNEL

Wasserman Honored by Chief Executives Forum

Chief Executives Forum, Inc., at its annual meeting in April at the La Coquille Club at Palm Beach Fla., honored Rene D. Wasserman by nominating and electing him to officership on its executive committee. Mr. Wasserman is Chairman of the Board of the Eutectic Welding Alloys Corp., Flushing, N. Y.

The membership of the Chief Executives Forum is restricted to the alumni of the Young Presidents' Organization, Inc., in which Wasserman has been active for many years.

The purposes of the Chief Executive Forum, like those of the Young Presidents' Organization, are to develop and promote the exchange of American business management ideas, experiences and practices and aggressively develop and support individual incentive, but not to carry on propaganda or influence legislation.

Alloy Rods Appoints Tomlinson

Alloy Rods Co. has announced the appointment of Ralph L. Tomlinson, Jr., as sales representative in the Greater Los Angeles area. According to E. R. Walsh, III, sales manager, at York, Pa., Tomlinson will operate from their El Segundo office and will be calling directly on industry as well as on distributors.

Mr. Tomlinson's experience in the welding industry includes more than 10 years in various capacities of sales and sales management.

Browning Elected President of Thermal Dynamics

James A. Browning AWS was recently elected president of Thermal Dynamics Corporation, Lebanon, N. H. Mr. Browning, professor of Mechanical Engineering at Dartmouth College and one of the founders of Thermal Dynamics, has previously served as director of research and development. The company manufactures plasma equipment, widely used for ultra-high temperature applications in research laboratories and in industry.

Kennedy Made Sales Manager

Jack P. Kennedy AWS was recently made sales manager of the Wayne Welding Supply Co., Inc., Fort Wayne, Ind.

He graduated from General Motors Institute with a B. I. E.–Welding Technology and became a welding engineer for Harrison Radiator Division of G. M. C. He was recently with the Welding Division, Westinghouse Corp. as a welding sales engineer and was midwestern district sales manager for the past two years.

M. W. Eddins Joins NAVCO

Mike W. Eddins AWS has joined National Valve and Manufacturing Co. (NAVCO) as the Welding Engineer in charge of all welding operations. NAVCO fabricates and field erects power piping systems for conventional and nuclear power plants.

Mr. Eddins formerly was associated with the Engineering Works Division of the Dravo Corp. A graduate of The Ohio State University in welding engineering, Mr. Eddins has been in the power piping design and fabrication field for the past ten years.

He is a past chapter president of the AMERICAN WELDING SOCIETY and a member of the American Society for Metals.

Nottingham Names Saddler

Jack R. Saddler has been appointed manager, South Atlantic District, by Walter G. Roe, manager—sales of J. B. Nottingham & Co., Inc., 441 Lexington Ave., New York 17, N. Y.

Mr. Saddler is responsible for sales and service of Nottingham portable equipment for multi-arc welding, stress relieving, and power distribution in the states of Maryland and Virginia including the Washington, D. C. and Norfolk-Newport News and Baltimore areas.

A graduate of the University of Delaware, Mr. Saddler has been a sales representative for the metallurgical division of P. R. Mallory & Co. and district sales manager of Eastern Malleable Iron Co.

Stano Promoted to District Manager

Matt L. Stano of Milwaukee, senior technical representative for Eutectic Welding Alloys Corp., Flushing, N. Y., has been promoted to district manager for southeastern Wisconsin. He will continue to service the southern half of the Milwaukee area while assuming his duties in newly created areas. Stano has been with Eutectic since early in 1955.

R. D. Wasserman

R. L. Tomlinson, Jr.

J. A. Browning

H. J. Bichsel Named Westinghouse Manager

Harry J. Bichsel AWS has been named manager of the Westing-Arc Department of the Westinghouse Electric Corp. He replaces Richard C. Lipps who has resigned.

Formerly engineering manager of the Westing-Arc Department at Buffalo, N. Y., Mr. Bichsel rejoins that product division there in the top position after a two-year absence during which he served as the corporation's European engineering representative in Geneva, Switzerland, and more recently as executive assistant to the vice president for general products.

A native of Salem, Ohio, he attended high schcol there and was graduated from Purdue University in 1940 with a Bachelor of Science degree in electrical engineering. He joined Westinghouse in the Graduate Student Program the same year. After a period in the corporation's Design School, he joined the Electronic Control Section of the Control Engineering Department at East Pittsburgh and has been engaged in the design, development and application of electric welding equipment ever since.

During the period from 1946 to 1957 he held various engineering and engineering management posts during which Westinghouse pioneered in the development, and wide use of rectifier-type welders, inert gas and CO_2 welding processes and equipment.

Mr. Bichsel has over 20 patents to his credit, most of which pertain to welding equipment and is a co-recipient of the corporation's Most Meritorious Patent Award for his work in the development of the West-ing Gun, a portable arc welding "gun" widely used in the automotive and shipbuilding industries.

The author of numerous technical papers and articles, Mr. Bichsel is a member of the American Welding Society and the American Institute of Electrical Engineers.

Prior to his European assignment in 1959, Mr. Bichsel spent 13 years with the Westing-Arc Department in Buffalo, N. Y. and resided in East Aurora, N. Y., where he was active in Boy Scout activities and other civic affairs.

Carlton to Manage O.E.M. Sales

Ray Carlton AWS formerly chief engineer at OMARK Industries, Inc., Portland, Ore., assumed the duties of manager—original equipment manufacturer sales, on June 1, Guy E. Sabin, general sales manager for the company, announced recently.

Carlton, one of OMARK's original three employees in 1948, has had extensive experience with all technical phases of the company's operations. He has served as chief engineer for the past six years, and prior to that was production manager and plant superintendent.

In his new position, Carlton will supervise original equipment manufacturer sales for all products in both the OREGON Saw Chain and OMARK Fastening Divisions, and will be responsible for policy, pricing and technical assistance and service to all O.E.M. customers.

MAC Valve Appoints Komendera Sales Manager

The appointment of J. B. Komendera AWS as sales manager was announced by Walter Ludwig, president, Mechanical Air Controls, Detroit 37, Mich. He will be responsible for sales of the complete line of "MAC" solenoid, pilot and mechanically operated air valves throughout the United States and abroad.

Prior to joining "MAC", Komendera was with the Valvair Corp. for over six years. He has also been associated with Greer Hydraulics, Inc., and the Timken Detroit Axle Co. in various sales capacities.

A member of the Society of Automotive Engineers, Engineering Society of Detroit and the AMERICAN WELDING SOCIETY, Komendera is an engineering graduate of the University of Detroit.

FitzSimons Appointed All-State Publicity Manager

Robert FitzSimons has been appointed publicity manager, All-State Welding Alloys Co., Inc., White Plains, N. Y., it was announced recently by Richard H. Mandel, executive vice president. As publicity manager, Mr. FitzSimons will coordinate all promotional activities in the technical and trade press, initiate feature stories and special events and supervise company publications.

Prior to joining All-State, Mr. FitzSimons was engaged in public relations for Allied Chemical Corp., Louis Weintraub Associates, Inc., New York City and for American Locomotive Co., Schenectady, N. Y. Earlier experience includes news editing and program directing for Armed Forces Radio Service in the Arctic.

Syntron Semiconductor Division Appoints Marketing Manager

Gene A. Powell has joined the Semiconductor Division of Syntron Co. as marketing manager, according to general manager Paul Bosted.

Powell will be responsible for direction of the Semiconductor Division's overall sales and marketing organization, including advertising, sales planning, public relations and sales literature.

H. Bichsel

Ray Carlton

J. B. Komendera

J. I. Scott, continues as sales manager, supervising all direct and field sales activities with Powell's overall direction.

Powell joins Syntron from General Instruments Corp., Chicago, where he served as district sales manager. He previously was marketing operations manager for the Semiconductor Division of Hoffman Electronics Corp., Evanston, Ill.

Powell is a member of the American Management Association.

C. W. Parker, Jr. Named A-C Marketing Manager

Charles W. Parker, Jr., has been named to the newly created position of general marketing manager, new products department, it was announced by Allis-Chalmers. He will have complete marketing and sales responsibility for the company's new products, materials and processes, coming principally from the central Research Division and the firm's many other development centers.

Along with the appointment announcement, the recently organized unit was renamed from Special Products to New Products, according to K. R. Geist, general manager.

Parker was Director of Sales Promotion, Industries Group, since June 1958, heading advertising, market analysis and training activities. Prior to that he was manager of the company's Philadelphia (Pa.) district sales office.

Griscom-Russell Advances Three

The Griscom-Russell Co. of Massillon, Ohio, manufacturer of power, process, nuclear and marine industrial equipment, has announced the promotion of Philip S. Otten, Charles D. Steffens and Robert W. Schroeder in its executive sales department.

Mr. Otten, who has been associated with the company since 1936, has been appointed assistant sales manager. He formerly was manager of special products. An authority on heat transfer equipment, Mr. Otten contributed substantially to the design of the steam generators fabricated by Griscom-Russell for the Enrico Fermi Atomic Plant, Monroe, Mich., and the Atomics International Plant, Hallam, Neb.

Mr. Steffens was formerly manager of sales research and has been named assistant manager of sales administration. A veteran of 35 years with the company, Mr. Steffens has specialized in the development and sales of evaporators and feedwater heaters.

Mr. Schroeder succeeds Mr. Otten as manager of special products. He has been associated with Griscom-Russell for nine years on the Company's Research and Development staff.

The Griscom-Russell Co. and its affiliate, C. H. Wheeler Manufacturing Co., Philadephia, Pa., manufacture pumps, heat exchangers, feedwater heaters, condensers, sea water distilling plants, nuclear and marine equipment.

Nippes Acting Head of RPI Department

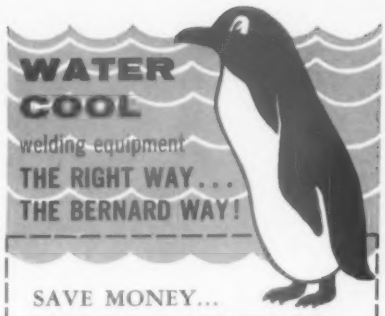
Dr. Ernest F. Nippes AWS, graduate of Rensselaer Polytechnic Institute, member of the faculty since 1939, professor of metallurgical engineering since 1954, has been named by the provost as acting head of the Department of Materials Engineering. He takes the post opened in the appointment of Dr. Arthur A. Burr as acting dean of the School of Engineering.

Dr. Nippes has been in charge of welding research at the Institute since 1949 and has won numerous honors for advances in that field. One of the most signal of these was the $2000 teaching award from the American Society for Metals. Other prizes were awarded for leadership in various fields of welding research and for four years running, Dr. Nippes and associates won the first prize of the AMERICAN WELDING SOCIETY for their work in resistance welding. He delivered the Adams Memorial Lecture for the AWS in 1958 and in 1959 was awarded the Miller medal for outstanding services in the AWS.

Dr. Nippes has engaged in extensive research under sponsorship of metal working industries. He recently returned from Soviet Russia where he was one of three American welding authorities invited to visit research centers in Moscow, Kiev and Leningrad. This visit was in return for the tour of three Russian welding experts to Rensselaer and other centers of the profession in this country. This was his third trip to Europe. He was a delegate of the AMERICAN WELDING SOCIETY to meetings of the International Institute of Welding in Germany in 1957 and in Yugoslavia in 1959.

Eutectic Names District Manager for Hawaii

Edward Zacavich has been named district manager for Hawaii by Eutectic Welding Alloys Corp., Flushing, N. Y. He was formerly a technical representative for Eutectic in San Diego, Calif. Before joining Eutectic, Zacavich held positions in engineering service for several West Coast manufacturing firms. Eutectic manufactures alloys and chemical aids for welding, brazing, and soldering, and is expanding its product and service facilities to meet the needs of Hawaii's fast-growing industry.



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For details, circle No. 16 on Reader Information Card

Westinghouse Appoints Two

Two executive promotions in the Westing-Arc Dept., Montevallo, Ala., plant of Westinghouse have been announced.

E. H. Turnock, formerly manager of the electrode engineering section, has been appointed senior engineering consultant to the manager of engineering. He will continue to be located at Montevallo, acting on electrode matters and technical assistance to foreign licensees.

Gail E. Saur, formerly supervisor of quality and process control, has been appointed supervisor of the engineering section at Montevallo. Saur will be responsible for engineering development and quality control of all products manufactured at Montevallo.

22 oz. welding torch—
business end of a new system that can clobber your welding costs

This new straight-through torch is the lightest, coolest and most maneuverable you can buy . . . yet it can handle wire at speeds up to 1170 ipm.

It's part of a new Westinghouse system for thin gauge welding that combines the speed and economy of semi-automatic welding with the maneuverability of stick welding.

To back up the torch there's a new wire drive system with a vernier adjustment that permits exact feed control heretofore impossible. The power source for the package is the proven Westing-Arc RCV silicon welder with built-in Dynamic Reactor.

For more information see the opposite page . . .

Westinghouse

For details, circle No. 17 on Reader Information Card

New Westinghouse SA-200 Welding System

Here are some of the advantages of the new Westinghouse SA-200 system:

22 OZ. TORCH has an exclusive 360° rotating nozzle that permits the operator to keep the switch in the most comfortable position for any welding job. The torch is air cooled, has a 15-foot cable, handles both mild, stainless steel and aluminum wire. It can be used with CO_2, argon or argon gas mixtures.

PRECISE WIRE SPEED CONTROL obtained from a vernier type potentiometer gives you exact wire speed required—as high as 1170 ipm. Both drive rolls are powered to provide positive wire feed.

HIGH EFFICIENCY 200 AMP RCV WELDER provides lower power consumption than is possible with any comparable system. Controlled output characteristics of this welder, combined with precision wire speed control and a highly maneuverable torch, provides the ultimate in welding gauge size materials.

THE WESTINGHOUSE SA-200 SYSTEM will enable you to have *all* of the advantages of semi-automatic welding and yet retain the versatility of stick electrode welding. All this with as much a savings as 50% in your welding cost. Designed for production welding, there is a continuous feed from a 25 lb. spool of wire, no slag removal, no stub loss, and with the highest deposition efficiency.

READY TO ADVANCE? Call your Westinghouse distributor for a demonstration, or write Westinghouse Electric Corp., Westing-Arc Dept., P.O. Box 2025, Buffalo 5, New York.

You can be sure . . . if it's Westinghouse.

J-10485

Alcoa Appoints Fish

The Aluminum Co. of America recently announced the appointment of William M. Fish as senior scientist in the Alumina and Chemicals Division of Alcoa Research Laboratories, located at E. St. Louis, Ill.

Born in Escanaba, Mich., and a chemical engineering graduate of Marquette University, Mr. Fish joined ARL in 1946. Previously, he was affiliated with the Swenson Evaporator Co., Harvey, Ill., and the G. S. Mepham Corp., E. St. Louis.

Gray Appointed ASM Editor

Allen G. Gray has been appointed editor of periodical publications for American Society for Metals, according to Allan Ray Putnam, managing director of the society. While retaining editorship of Metal Progress, ASM's magazine of materials and process engineering, he will now have general editorial supervision of all society periodicals, including Metals Review, Review of Metal Literature, Metals Engineering Quarterly and Transactions Quarterly.

A. O. Smith Appoints Two

The appointments of W. V Raszka and J. F. Colosimo as sales engineers in the Mid-East and Detroit districts respectively have been announced by A. O. Smith's Welding Products Div., Milwaukee, Wis.

Raszka, holder of a degree in mechanical engineering from Worcester Polytechnic Institute, was production manager for the Budd Co. prior to his recent appointment. Colosimo is a recent graduate of Notre Dame University.

Wellhofer Appointed Page Steel Plant Manager

Ernest S. Wellhofer has been appointed plant manager of the Monessen, Pa., plant of Page Steel and Wire Division of American Chain & Cable Co., Inc.

Mr. Wellhofer joined the company's engineering staff at Wilkes-Barre, Pa., in December 1936. After serving as chief engineer for wire rope, he was appointed plant manager of the company's wire rope plant at Wilkes-Barre in 1955 which position he held until his recent appointment.

Joseph H. Ritts has been appointed plant manager of the Wilkes-Barre, Pa., plant to succeed Mr. Wellhofer. Mr. Ritts has been assistant plant manager at Wilkes-Barre since December 1956. Prior to that he had been plant manager of the Pittston, Pa. plant. He started with the company at Wilkes-Barre in November 1942.

K. R. Geist Named A-C General Manager

The appointment of Kenneth R. Geist as general manager of the newly formed Special Products Department, Allis-Chalmers Mfg. Co., has been announced by W. G. Scholl, executive vice president.

In the capacity Geist will develop new businesses for the company. Products, materials and processes which will be handled by this department will come principally from the Allis-Chalmers Central Research Div. and from the firm's other research and development centers.

Wymss Appointed All-State Comptroller

LeRoy Wymss, CPA, has been appointed comptroller for All-State Welding Alloys Company, Inc. White Plains, N. Y., and subsidiary companies. As comptroller, Mr. Wymss will institute a program of departmental budgeting. The new system has been made necessary by the continued growth of the company and is consistent with accounting practices in the welding and metalworking industry. Mr. Wymss is a member of the National Association of Accountants and the Connecticut Institute of Certified Public Accountants.

Climax Appoints John W. Goth

John W. Goth has been appointed manager of foundry sales for Climax Molybdenum Co., a division of American Metal Climax, Inc., Elwin E. Smith, general sales manager, announced recently.

Mr. Goth, who was previously head of the company's Chicago sales office, will continue to have his headquarters in that city. The company maintains other foundry sales offices in Dayton, Ohio and New York City.

After two years with U. S. Vanadium Co., Mr. Goth joined Climax Molybdenum Co. in 1954 as a resident physical metallurgist at the company's mine in Climax, Colo. Prior to his appointment as a sales representative in the Chicago area in 1958, he had been for two years, assistant to the manager of metallurgical development for Climax in Denver, Colo.

Lenco Appoints Sales Manager

Roy W. Poe has been appointed sales manager for Lenco, Inc., of Jackson, Mo. Poe will have charge of sales and advertising of the company's entire line. Prior to joining Lenco, Poe was Midwest District Manager for Welding Engineer Publications and also served as vice president of Tweco Products for 12 years. He will make his home in Jackson, Mo., where the Company's operations are located.

Diehl Named Sales Engineer

T. T. (Ted) Diehl has been appointed sales engineer specializing in electrodes, automatic wires and fluxes by the Weber Welding Supply Co., Hobart Distributors, Pittsburgh, Pa.

Tec Torch Appointments

Leon A. Micheline has been appointed sales manager and Raymond J. Wallace was made western regional sales representative of the Tec Torch Co., Inc., East Rutherford, N. J.

Micheline advanced to his new position from distributor sales representative and will be responsible for planning and coordinating national sales activities through regional offices.

Wallace will operate from the regional Tec sales office and warehouse facilities located at 2522 W. 9th St., Los Angeles, Calif. He was formerly with General Electric Co.'s Welding Division and the Sager-Spuck Welding Supply Co. for 23 years.

Harris Calorific Expands Engineering Staff

Stevenson M. Taylor AWS, executive vice president, Harris Calorific Co., recently announced the appointment of three men to the company's engineering staff: Frank Hach, Jr., chief industrial engineer; Alfred E. Burnell and Joseph J. Okladek, product engineers.

Hach, a Case Institute of Technology graduate, joined Harris after almost ten years with Lincoln Electric where he was a methods engineer. Prior to this he served in similar capacities at Pesco Products and Euclid Tool, both of Cleveland.

Al Burnell was formerly chief engineer of the K-G Division of Air Products, Inc. at Allentown, Pa. He had been with this company since 1951. Burnell is a graduate of Stevens Institute of Technology, Hoboken, N. J.

Joseph J. Okladek was born in Poland, moved to Belgium as a child. A graduate of the Institut des Arts et Metiers in Brussels, Okladek joined Canadian Westinghouse in 1951. In 1953 he left Westinghouse to become manager of the Oxy-Acetylene Section of the Technical Development Department of Canadian Liquid Air.

Amperex Promotes R. Gabbei

The promotion of Roger Gabbei to the position of midwest regional sales manager was recently announced by Frank Randall, president of Amperex Electronic Corp.

Mr. Gabbei had been manager of the Chicago Sales Office for the past four years.

As regional sales manager, he will be responsible for servicing OEM accounts throughout the entire midwest. His headquarters are located at the Chicago Sales Office, 7440 W. N. Ave., Elmwood Park, Ill.

Burdett Appoints Barrett

A. J. Drake AWS, general manager of the Burdett Oxygen Co. of Norristown, Pa., recently announced the appointment of Jared "Jerry" Barrett to sales manager.

Frank Vener will replace J. Barrett as territory salesman.

Barrett, a member of the AMERICAN WELDING SOCIETY since 1952, joined the Burdett Oxygen Co. as a salesman in August 1958.

Lincoln Appoints Welding Engineer

Lincoln Electric Co. of Cleveland, Ohio, has announced the appointment of Donald A. Dumuth to their staff of field engineers. Dumuth has been assigned to Lincoln's Chicago District Office. A graduate of Kent State University with a Bachelor of Science degree in Industrial Technology, Dumuth has undergone a one year training program at Lincoln to equip him to properly handle customer requirements, and engineer the application of arc welding to reduce manufacturing costs.

Obituaries

F. Lee Rodgers

F. Lee Rodgers AWS, 69, founder and senior partner of Rodgers Welding Supply, Buffalo, N. Y., died on June 30th. Mr. Rodgers served as a 1st Lieutenant in World War I having fought in the Battle of the Marne. He was associated with the Oxweld Railway Service and the Linde Co. from 1919 until 1940, at which time he founded Rodgers Welding Supply. He was a Life Member of the AMERICAN WELDING SOCIETY.

Charles P. Feebusch

Charles P. Feebusch, 80, nationally known brazing and welding authority, died July 8 in Chicago following a long illness. He had retired two years ago as president of Gasflux Supply Co. of Chicago.

Born in New York City, Mr. Feebusch had served as consulting engineer and sales executive for Union Carbide Co., N. Y., and Bastian-Blessing Co., Chicago, before opening his own business. Earlier he supervised construction of several famous New York churches and mansions.

During World War II, Mr. Feebusch was a consultant to the War Production Board on brazing and welding. He was a longtime member of the AMERICAN WELDING SOCIETY.

Survivors include a niece, Mrs. Katherine Stoller, Brooklyn, N. Y., and three nephews, Joseph F. Feibusch, Jr. and Philip Feibusch, Levittown, L. I., N. Y., and Raymond Feibusch, Fort Smith, Fla.

William K. Sproule

William Kelvin Sproule, consulting metallurgist with the Development and Research Division of The International Nickel Co., Inc., died in New York on August 8th, after a long illness. He was 48 years old.

Mr. Sproule had been associated with International Nickel since June, 1937, when he joined the Research Department of The International Nickel Co. of Canada, Limited, at Copper Cliff, Ontario. He became superintendent of Research at Copper Cliff in 1948, and served in that capacity until his appointment as consulting metallurgist, in 1956.

A. J. Fisher, Jr.

A. J. Fisher Jr., executive vice president, Metal & Thermit Corp., died Friday, August 11, 1961, at Norwalk Hospital, Norwalk, Conn. He was 47.

Mr. Fisher joined Metal & Thermit Corp. in 1955 as a member of the market research department, and was elected executive vice president in 1960. Prior to this association, he was manager of chemical sales development for U. S. Industrial Chemicals, Inc., N. Y., and president of U. S. Polymeric Chemicals, Inc., Stamford, Conn.

Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D.C.

2,947,847—Shielded Metal Arc Welding Process—James R. Craig, Pleasantville, and Harry E. Rockefeller, Bronxville, N. Y., Frank T. Stanchus, West Orange, N. J., and Norman Davis, Los Angeles, Calif., assignors to Union Carbide Corporation, a corporation of New York.

This patent relates to the electric arc welding of steel where a metal electrode and a metal workpiece are connected to a source of welding current. The electrode is fed toward the workpiece to establish and maintain an arc and welding zone between the electrode and workpiece. A stream of a shielding gas is supplied to the arc and solid nonmagnetic granulated welding composition is suspended in a part of the stream. Such welding composition is composed of a fused and crushed silicate selected from a listed class of silicates and having a slag-producing component capable of fusion in the arc to produce a slag. A metal halide electrical conductivity-imparting component is also present in the welding composition. The gas and solid stream are fed to the electrode at a rate of between about 10 and about 50 cfh. The rate of suspending the welding composition in the gas stream is coordinated with the rate of fusion of the electrode so that about 0.2 lb of composition per pound of rod to about 1.5 lb of composition per pound of rod are used to form a slag blanket on the weld produced by the arc.

2,947,848—Method and Apparatus for Truss Core Sandwich Welding—David Sciaky, Chicago, Ill., assignor to Welding Research, Inc., Chicago, Ill., a corporation of Illinois.

This method relates to the resistance welding of two workpieces to each other and where the workpieces comprise closed channels extending the length of the workpiece. In the method, the workpieces are separated at a location in advance of their welding contact point, and pressure is applied to the workpieces at their welding contact point where welding current can provide the weld action. The weld current is supplied to one workpiece at the location of separation in a manner to cause current to flow in one workpiece to the point for weld action and then return by flowing in the other workpiece to the location of separation. The workpieces are moved progressively by the weld point for weld action and the cooling fluid is flowed through the closed channels during the weld operation for cooling action.

2,948,061—Method of Fabricating Cylindrical Shell Structures—Fred A. Carstens, Milwaukee, Wis., assignor to A. O. Smith Corporation, Milwaukee, Wis., a corporation of New York.

The present patent relates to a method of fabricating a cylindrical structure from a plurality of trapezoidal plates, each of which has a square end and correspondingly equal angles. Special positioning of the plates and special welding action are used to form a cylindrical structure.

2,948,803—Electric Arc High-Alloy Metal Deposition—Jack L. Wilson, Niagara Falls, Harry E. Rockefeller, Bronxville, and Thomas E. Butler, Niagara Falls, N. Y., assignors to Union Carbide Corporation, a corporation of New York.

In the present patent, a high temperature, nonferrous alloy electric arc welding process is disclosed. Initially a welding arc is energized between the end of a bare wire electrode composed essentially of cobalt and a metal workpiece. The end portion of the electrode is coated with powdered nonferrous metal particles composed mainly of cobalt, chromium and tungsten, and the electrode is continuously fed toward the arc. An annular stream of inert gas is supplied around the electrode to protect the coating, arc and weld zone from the surrounding atmosphere. The ratio of metal deposited by the powdered metal is substantially equal to that deposited by the electrode to produce a high temperature alloy in a slag-free weld deposit.

2,948,804—Magnetic Force Resistance Welders and Method of Controlling the Phase Relation of the Magnetic Force Applied to the Electrodes with Reference to the Phase Relation of the Welding Current—Arthur W. Schueler, Ernest J. Funk and Lawrence W. Mecklenborg, all of Cincinnati, Ohio, assignors to Precision Welder & Flexopress Corporation, Cincinnati, Ohio, a corporation of Ohio.

The present patent relates to a magnetic force welding system wherein a pair of welding electrodes are provided for clamping the work there between and with one of the electrodes being movable toward and away from the other electrode. Energization winding means are provided in association with both of the electrodes and means are provided to move the one electrode towards the other. A first welding transformer is provided and has its secondary winding connected to the welding electrodes, while a second transformer is present and has its secondary winding connected to the energization winding which controls movement of the one electrode toward the other. Control devices and means are present to connect the transformers together so that operation of the transformers and control means can be simultaneously initiated.

2,948,805—Method of Enclosed Welding—Jozef Ter Berg and Andre Larigaldie, Bobigny, France, assignors to North American Philips Company, Inc., New York, N. Y., a corporation of Delaware.

This patent relates to a method of enclosed welding to two members with similarly-shaped end surfaces. These members are positioned with the end surfaces spaced apart to form a welding space and an elongated welding electrode is inserted into the space, which electrode has a core with a nonconductive, slag-forming coating thereon. The welding action is obtained while moving the electrode into the welding space and the sides and bottom of the welding space are at least partially enclosed during the welding action.

2,949,391—Method and Apparatus for Automatic Torch Positioning—Nelson E. Anderson, Berkeley Heights, N. J., assignor to Air Reduction Company, Incorporated, New York, N. Y. a corporation of New York.

Anderson's patent relates to apparatus for maintaining a predetermined separation of the tip of a flame supporting torch from a workpiece. The apparatus includes means for passing electrical current through the flame and between the torch tip and the workpiece. Other means are present and are automatically responsive to variations in the electrical conductivity of the flame to reduce the difference between the actual and a predetermined separation of the torch tip from the workpiece. The patent particularly covers an improved type of a torch tip having a special construction so that the total electrical resistance of the flame between the torch and the workpiece is more responsive to changes in its length with changes in the spacing of the torch tip from the workpiece to facilitate the automatic control action desired.

2,949,526—Gas Shielded Arc Torch—Clifford W. Hill, Mountainside, and William J. Blanchard, Sr., Parlin, N. J., assignors to Union Carbide Corporation, a corporation of New York.

This patent is on a gas shielded arc torch which includes a torch head for supporting an electrode and a gas-directing nozzle surrounding the electrode. A neck is joined to the head for supplying current to the electrode and gas to the nozzle while a handle is joined to the neck to manipulate the torch. The head is constructed of metal of high heat conductivity for rapid conduction of heat away from the arcing tip of the electrode to the handle. A cooling jacket and water circulating means are provided in the handle to aid in removal of heat from the handle.

2,949,527—Electric Arc Welding—John A. Lucey, Newcastle-upon-Tyne, England, assignor to The British Oxygen Company Limited, a British Company.

This patented apparatus is for welding a substantially horizontal curved seam between an upper and a lower metal plate which together define a portion of the curved shell in which the radius of revolution for the shell varies in accordance with the position along the axis of revolution. A support for a welding head is also present and two driving rollers are attached to the support and spaced thereon so that one will drivingly engage the top edge of the upper plate and the other roller will drivingly engage the lower plate to be welded. Control means are provided for the drive of the rollers so that the apparatus functions to drive these rollers at different peripheral speeds whose magnitudes are correlated by controlling means to insure an approximately steady movement of the welding head mounted on the support as it is moved along the weld seam.

2,949,528—Method and Device for Flux-Covered Electrode Welding—Arthur A. Bernard, R. R. 2, and Richard A. Bernard, R. R. 1, both of Chicago Heights, Ill.

The present novel electrode holder includes a pair of tubes, and an electrode gripping jaw secured to similar ends of each tube. Each jaw is internally recessed for a substantial portion of its length and such recess connects to a conduit formed in the pair of tubes whereby cooling fluid can be circulated from one tube to the other through the jaws to remove heat from the jaws during welding action.

2,950,189—High Titanium Content Brazing Compositions—Robert G. Ames, Cresskill, N. J., assignor to The B. G. Corporation, Ridgefield, N. J., a corporation of New York.

Ames patent is on an alloy consisting essentially of copper, silver, indium, nickel and titanium. The ingredients are present in an amount totalling 100% in certain specified proportions including about 15.5 to 30% titanium.

2,950,376—Method and Apparatus for the Manufacture of Sections—Alfred Wogerbauer, 9 Greilstrasse, Linz, Austria.

In this method for continuously manufacturing profiles, at least two metal strips are fed one beside the other through a shaping zone and the strips are shaped in such zone to form trough-like sections with their open sides facing in the same direction and with free lateral edges. At least one of the trough-like sections is twisted progressively out of its plane of feeding and it is moved to a position in which the lateral edges of the trough-like sections abut against each other to provide a tubular member of desired cross-sectional shape. Then such edges are welded together.

2,950,379—Stud Welding Means and Method—Edward Dash, 1540 Seabright Ave., Long Beach, Calif.

This patent is on a ferrule for use in welding a stud to a sheet or a plate. The ferrule includes a sleeve of refractory material having a passage therethrough for shielding the stud, and a solid homogeneous metal member is provided at one end of the sleeve for absorbing heat from the sheet or plate during a welding operation.

Current Welding LITERATURE

For copies of articles, write directly to publications in which they appear. A list of addresses is available on request.

Aluminized Steel

Welding of Aluminized Steel Sheet, T. M. Molossi and J. H. Nicholls. *Sheet Metal Industries*, vol. 38, no. 406 (Feb. 1961), pp. 95–98, 146.

Aluminum

Aluminum Can Now Be Mig Spot Welded, I. A. MacArthur and A. A. Dolomont. *Modern Metals*, vol. 16, no. 9 (Oct. 1960), pp. 52, 56, 58.

Fluxless Solder Cuts Aluminum Window Costs, C. James. *Welding Engr.*, vol. 46, no. 2 (Feb. 1961), p. 53.

Automobile Manufacture

Arc Spot Welding In Automotive Production, B. L. Kosnik. *SAE*—Paper 329C for meeting Mar. 13–17, 1961, 9 pp.

Arc Welding Rear Axle Housings and Related Assemblies, W. F. Williams and S. M. Spice. *SAE*—Paper 329A for meeting Mar. 13–17, 1961, 10 pp.

Gas Shielded Fusion Welding In Automotive Production, R. E. Brooks. *SAE*—Paper 329B for meeting Mar. 13–17, 1961, 9 pp.

New Rambler Plant Works Out Its Own Assembly Methods. *Can. Machy. & Metalworking*, vol. 72, no. 2 (Feb. 1961), pp. 79–83; See also *Can. Metalworking* vol. 24, no. 3 (Mar. 1961), pp. 25–29.

Brazing

Why You Should Braze Small Diameter Piping, A. W. Swift. *Welding Engr.* vol. 46, no. 1 (Jan. 1961), pp. 44–46.

Carbon Dioxide Welding

Horizontal-Vertical Welding, in CO_2 with Plate of Large Thickness V. N. Suslov and S. I. Klepikov. *Welding Production* (English translation of Svarochnoe Proizvodstvo), no. 3 (Mar. 1960), pp. 9–13.

Cast Iron

Ductile Iron in Steel Mills, C. R. Isleib. *Iron & Steel Engr.*, vol. 38, no. 2 (Feb. 1961), pp. 83–90.

Copper

Can Copper Alloys Hold Line at Ultra-low Temperatures? C. L. Bulow. *Iron Age*, vol. 187, no. 10 (Mar. 9, (1961), pp. 92–94.

Carbon Block Brazing of Stranded and Solid Copper Wire, M. G. Steele. *Wire & Wire Products*, vol. 35, no. 10 (Oct. 1960), pp. 1317–21, 1456–58.

Weldable Copper, J. G. Young and K. J. Clews. *Welding & Metal Fabrication*, vol. 28, no. 10 (Oct. 1960), pp. 404–407.

Cryogenic Materials

Welding and Heat Treating 60-Ton Cryogenic Vessel W. H. Vetter. *Metal Progress*, vol. 79, no. 2 (Feb. 1961), pp. 88–90.

Dissimilar Metals

Automatic Welding (Overlaying) of Steel with Copper Electrode, S. M. Katler and V. A. Sinikov. *Welding Production* (English translation of Svarochnoe Proizvodstvo) no. 3 (Mar. 1960), pp. 4-8.

Tig Welding Joins Copper to Stainless, J. M. Gerken and D. B. Kittle. *Am. Mach./Metalworking Mfg.*, vol. 104, no. 23 (Nov. 14, 1960), pp. 126–127.

Welding Dissimilar Metals. *Metal Industry*, vol. 97, no. 23 (Dec. 2, 1960), pp. 461–462.

Distortion

Shrinkage Control in Welding, O. W. Blodgett. *Civ. Eng.* (N. Y.), vol. 30, no. 11 (Nov. 1960), pp. 56–61.

Electron Beam Welding

Electron Beam Welds Pay Off for Bellowsmaker. *Steel*, vol. 148, no. 10 (Mar. 6, 1961), pp. 78–79.

Electron Beam Welds Molybdenum Sheets, E. G. Thompson, E. C. Bernett and H. Binder. *Steel*, vol. 148, no. 13 (Mar. 27, 1961), pp. 166–167.

Electroslag Welding

Electroslag Welding of 1Kh18N9T Steel Plate, I. D. Davydenko, V. F. Koshevoi and A. I. Nosenko. *Welding Production* (English translation of Svarochnoe Proizvodstvo), no. 3 (Mar. 1960), pp. 37–44.

Hard Facing

Automatic Wear-Resistant Hardfacing in Mass Production, A. P. Suschenko. *Welding Production* (English translation of Svarochnoe Proizvodstvo), no. 3 (Mar. 1960), pp. 44–49.

New Stellite Hard-facing Process. *Machy.* (Lond.), vol. 98, no. 2521 (Mar. 8, 1961), pp. 538–539.

Wear-Resistant Hardfacing with "Powder-Tape" Electrode, O. A. Bakihi, E. F. Belousov, G. P. Klekovkin, V. M. Solovskii and T. V. Sumina. *Welding Production* (English translation of Svarochnoe Proizvodstvo), no. 3 (Mar. 1960), pp. 50–55.

Joints

Fatigue in Metal Joints, R. G. Crum. *Machine Design*, vol. 33, no. 7, no. 8 (Apr. 13), pp. 176–178.

Nuclear Reactors

Reactor Gets Repair-Free Welds. *Iron Age*, vol. 187, no. 7 (Feb. 16, 1961), pp. 106–107.

Oxygen Cutting

Automatic Profiling of Tube Ends. *Engineer*, vol. 211, no. 5489 (Apr. 7, 1961), pp. 556–557.

Further Studies of Iron-Oxygen Combustion in Gas Cutting, A. A. Wells. *Brit. Welding J.*, vol. 8, no. 3 (Mar 1961), pp. 79–85.

Oxygen Cutting—Report on Research Work for A. 4 (FM. 10) Committee 1950–1959, A. A. Wells. *Brit. Welding J.*, vol. 8, no. 3 (Mar. 1961), pp. 86–92.

Pipe Lines

Automatic Welding Hits Pipeline Right of Way, P. Reed. *Oil & Gas J.*, vol. 59, no. 5 (Jan. 30, 1961), pp. 84–85.

Double-Jointing Came Long Way in '60 . . . and Greater Progress Foreseen for '61, P. Reed. *Oil & Gas J.*, vol. 59, no. 7 (Feb. 13, 1961), pp. 70–73.

Power Supplies

How to Select and Use Proper Welding Power Sources, D. H. Hawes. *Welding Engr.*, vol. 46, no. 1 (Jan. 1961), pp. 35–38.

Pressure Welding

Recent Work on Pressure Welding, R. F. Tylecote. *Welding & Metal Fabrication*, vol. 28, no. 12 (Dec. 1960), pp. 191–194.

Resistance Welding

Fundamentals of Projection Welding, D. D. Williams. *Welding Engr.*, vol. 45, no. 11 (Nov. 1960), pp. 40–42.

How to Get Most From Your Resistance Welder, H. Bach. *Welding Engr.*, vol. 46, no. 1 (Jan. 1961), pp. 42–43.

Long-Armed Welder Reaches "Inaccessible" Spots. *Am. Mach./Metalworking Mfg.*, vol. 104, no. 21 (Oct. 17, 1960), pp. 106–107.

Magnetic Force Welding, C. A. Rowlands. *Welding & Metal Fabrication*, vol. 28, no. 12 (Dec. 1960), pp. 474–481.

Sandwich Construction

New Way to Make Stainless Honeycomb, G. J. Crites. *Am. Mach/Metalworking Mfg.*, vol. 105, no. 4 (Feb. 20, 1961), pp. 100–101.

Shipbuilding

"Brave" Class Fast Patrol Boats, R. C. Du Cane. *Welding & Metal Fabrication*, vol. 29, no. 2 (Feb. 1961), pp. 42–49.

Development of Structural and Metallurgical Requirements for Welded Hulls, R. T. Young. *Brit. Welding J.*, vol. 8, no. 2 (Feb. 1961), pp. 43–49.

Stud Welding

Stud Welding System Speeds Curtain Wall Production, H. P. Blood. *Modern Metals*, vol. 16, no. 10 (Nov. 1960), pp. 88–89.

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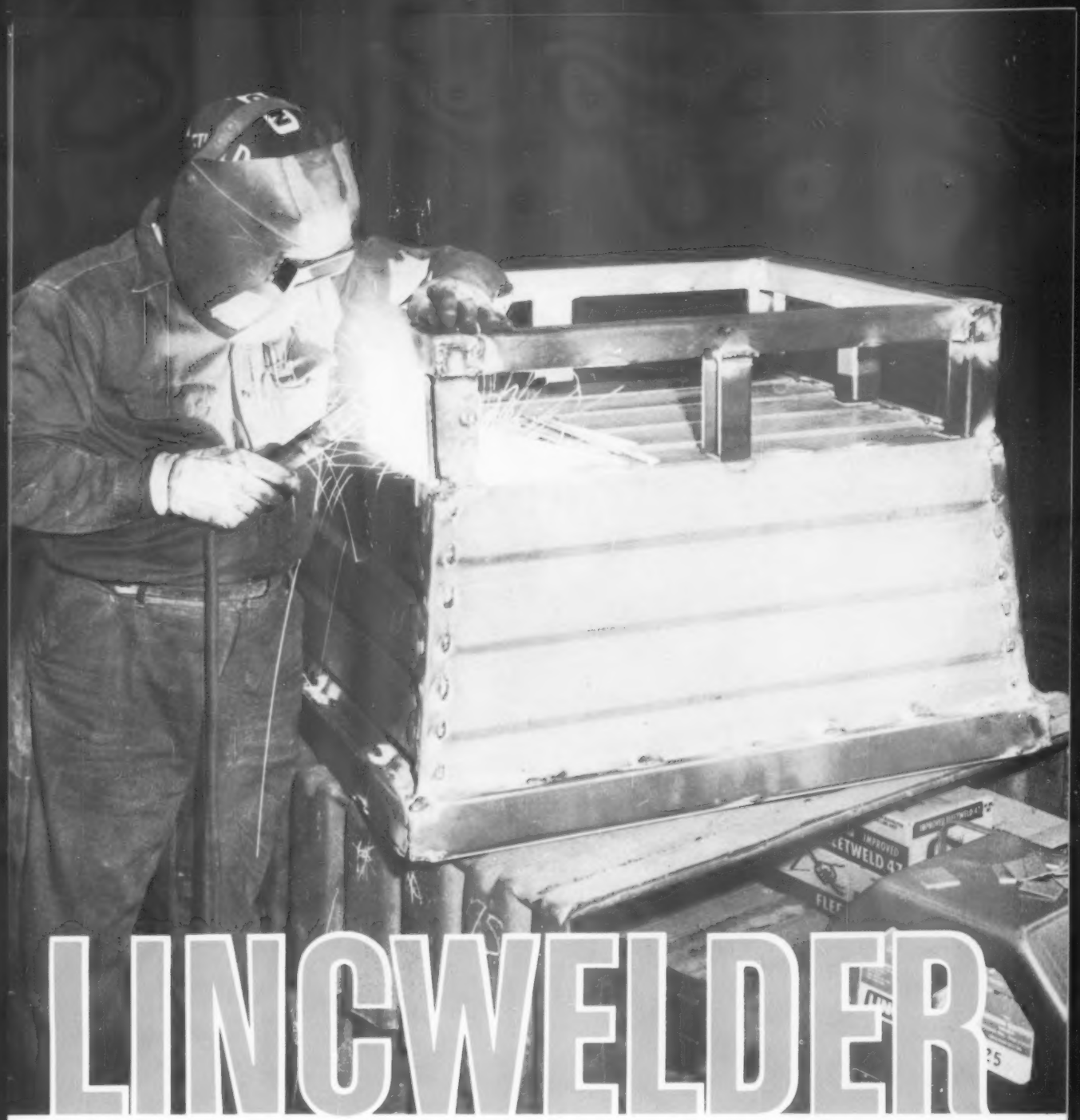

LINCWELDER

You can use just about any welder made for light fabrication, repair or maintenance welding. You can, that is, if you're not too concerned with the job you'll get or what it will cost. Take a few moments, won't you, to read how Lincoln—**Lincwelders**—are specifically designed for this kind of work and how they can improve weld quality and reduce both your equipment and job costs.

These are LINCWELDERS on the job

Light fabrication is simple with an AC-225-S **Lincwelder** because of its high current capacity, exceptional arc stability and high open-circuit voltage. Lets you handle iron-powder electrodes up to $\frac{5}{32}$-inch in diameter. These usually require a much larger machine. This capability lets you increase production, lower your costs. There simply is no machine made comparable to the AC-225-S, and none which sells at a competitive price which can do so many jobs so well.

Automotive repair shop makes good use of AC-180-S **Lincwelder** for general repair and maintenance work. Machine operates on standard single-phase, 230-volt power, needs no special wiring. Operates all day for about 32¢. Its low initial price and low operating cost means years of low-cost, trouble-free service. Machine furnished complete with headshield, cables, ground clamp, electrode holder, sample electrodes, instructions . . . everything you need to weld.

Lincwelder is a name applied to machines made for light to medium duty fabrication and maintenance. Two of these types of machines are discussed here. First, a DC, motor-generator, the second, an AC, transformer welder.

In the entire history of the welding industry, probably more men have been trained for "light-duty" work on **Lincwelder** motor-generators and have subsequently used them in more kinds of applications than any other welder ever made. Here's a breed of machines that is noted for delivering a sure, steady DC current. Here are machines equipped with dual continuous controls which let the operator set the exact current and voltage settings he needs to do a particular job according to his particular style. This kind of control lets the man get on top of his job quickly, produce better welds—faster—at less cost. These machines are just plain perfect for repair shops, garages, general maintenance departments, wherever DC welding is done on sheet metal, angles, channels and other light materials. And, of course, they can easily handle most stainless, non-ferrous and hardsurfacing jobs, too.

But maybe your shop uses one of the new electrodes that demands AC heat. If this is the case, you can get no finer AC transformer welder for light or medium-duty welding than the **Lincwelder** AC-180-S or the AC-225-S. Thousands of the smaller units have been sold for use in every conceivable type of application from the small captive job shop, the independents, and farms. No wonder. Here is a machine that comes equipped with everything you need to weld . . . electrode holder, ground clamps, cables, headshield, even sample electrodes. Does all kinds of jobs besides welding . . . hardsurfacing, thawing frozen pipes, cutting metal, etc. And the newer, companion AC **Lincwelder**, the AC-225-S, does all these things and more. Why? Simply because it has a higher open-circuit voltage which lets you handle the new, fast iron-powder electrodes in sizes up to 5/16". Low cost? This machine which comes complete—just as the AC-180-S—sells for less than most competitive 180-amp machines.

LINCOLN WELDERS

Why not consider putting one or more **Lincwelders** to work in your shop today? Want more information? See your local Lincoln field engineer . . . he's a specialist in welding. Or write direct for bulletins listed on the next page.

Lincwelder motor-generator sets are equipped with dual continuous controls. These let the operator select the precise heat and voltage settings to suit both his style and the particular task at hand. Here, **Lincwelder** is used on typical repair job on pipe. Many of these machines purchased more than thirty years ago are still operating, still delivering top welding performance. The most elementary sort of maintenance is required . . . usually just a change of brushes is all that is needed to keep them in top running condition.

Most stainless welding electrodes require DC. Here, **Lincwelder** motor-generator delivers steady DC current on stainless-steel sink repair job. But these machines are hard to beat for any welding be it on carbon steels, alloy or stainless steels, as well as non-ferrous metals. In every instance, they assure accurate control of penetration, great arc stability and thus top-quality welds at highest possible speeds. These characteristics assure you of getting low-cost performance.

LINCWELDERS

Motor-Generators—DC

Lincwelders are noted for rugged construction combined with light weight and portability. Available in 180 and 250-amp sizes. NEMA rated at 30% duty cycle, 30 volts. Available for 60 or 50-cycle, 2 or 3-phase supplies. Operating speed is 3600 rpm. For more information, request bulletin 4101.1.

LINCWELDERS

Transformer—AC

Lincwelder transformer machines are made in two sizes, 180 and 225 amps. Both are 20% duty cycle, 30-volt machines, available for 60 or 50-cycle, single-phase power supplies. The AC-180-S is NEMA rated and meets REA requirements for limited input machines. For more information, request bulletins 4601.10 and 4610.1.

THE LINCOLN ELECTRIC COMPANY

Dept. WW-28123 Cleveland 17, Ohio

The World's Largest Manufacturer of Arc Welding Equipment and Electrodes

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New Literature

Booklet on Grinding Stresses

The Grinding Wheel Institute, 2130 Keith Bldg., Cleveland 15, Ohio, has announced publication of an 81-page booklet, "Grinding Stresses: Cause, Effect and Control." This comprises the collected papers, which have been published as articles in the trade press, and is based on research sponsored by the Grinding Wheel Institute and the Abrasive Grain Association at Mellon Institute.

This compiled information offers proof that good grinding is not detrimental to fatigue strength. This work especially shows the grinding process to be a much maligned whipping boy. Definite reason has been shown to believe that fatigue strength in most normal grinding is not affected appreciably. Under conditions which are not very far removed from normal practice today, grinding can actually improve the fatigue strength of a part.

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Welding Machine Described

New bulletin No. 5300.1 describes vapor-shielded arc welding and the new semi-automatic "Innershield Squirt" and full automatic "Innershield" welders being manufactured by Lincoln Electric Co. Cleveland 17, Ohio. Typical process applications are illustrated. Performance characteristics and process speeds are compared with manual shielded metal arc and semi and full automatic submerged-arc welding. Construction details and mechanical features of the welding equipment are also listed.

For your free copy, circle No. 52 on Reader Information Card.

Stationary, Portable Manifolds

A comprehensive 12-page catalog describing a complete line of industrial gas manifolds is now available from Linde Co., Division of Union Carbide Corp., 270 Park Ave., New York 17, N. Y. Included in this catalog are twenty-one stationary manifolds designed for use with oxygen, acetylene, argon, nitrogen, hydrogen, methane, propane, helium, butane and other industrial gases. Manifolds described range from automatic change-over types that can accommodate unlimited numbers of cylinders to ready-to-install manual change-over types.

Many illustrations of actual manifolds are shown. Dimensional layouts of representative manifolds are also included for use in tailoring an installation to a user's exact needs. In addition to the 21 stationary manifolds, two portable manifolds, the Oxweld M-3 for oxygen and the Oxweld M-2 for acetylene are also described. The M-3 weighs only 10 lb and the M-2 weighs only 15 lb. These portable manifolds are ideal for field use. They are easy to move and can be set up by one man. Cylinder leads are flexible so that both of these manifolds can be used on uneven ground.

For your free copy, circle No. 53 on Reader Information Card.

Programmed Stress Relieving

Hobart Brothers Co., Troy, Ohio, has released folder DM-157, which describes a 400-cycle induction heating unit and tells how it simplifies the preheating and stress relieving of arc welded pipe joints. Automatic operation by means of strip chart program controller is described and illustrated. Also shown are typical installations.

For your free copy, circle No. 54 on Reader Information Card.

Bulk Supply Systems Described

Bulk supply systems for gaseous and liquid oxygen, nitrogen, and argon are described and illustrated in a new 24-page booklet (N-155) available from the National Cylinder Gas Division of Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

Specifications, capacities and space requirements for NCG liquid converters ranging in capacity from 35,000 to 1,390,000 cu ft, for tow and tube high pressure gas trailers, and for cylinder bank fill units are included. A distributor liquid pumping unit which enables NCG distributors to fill high pressure cylinders at their own plants also is described.

Information on and photographs of equipment used for transportation of liquid products and high pressure gases are included in the publication. A section provides data on cylinder manifolds which are recommended for installation where gas volume is not large enough to warrant a bulk supply unit.

The booklet contains brief descriptions of the industrial and medical gases produced by NCG, and lists the company's sales offices.

For your free copy, circle No. 55 on Reader Information Card.

Hard Surfacing Cooling Data

A new $8^1/_2$ x 11 Technical Data Sheet (No. T-4) outlining procedural recommendations for controlled cooling of Colmonoy hard-surfacing overlays when applied to Martensitic 400 Series stainless steels is now available from Wall Colmonoy Corporation, 19345 John R. St., Detroit 3, Mich.

The literature includes separate discussions of procedure for (1) A.I.S.I. Types 403, 410, 416 and 420 stainless steel and (2) A.I.S.I. Types 440A, 440B and 440C stainless steel. An isothermal transformation diagram for Type 410 stainless steel is also included.

For your free copy, circle No. 56 on Reader Information Card.

Gas Regulator Catalog

A completely new, 40-page catalog on regulators for the accurate control of industrial gases in all applications has just been issued by Air Reduction Sales Co., 150 E. 42 St., New York 17, N.Y. The catalog also includes information on accessory equipment available with the various regulators.

Covering the widest choice of gas precision regulators available today, the catalog provides quick-reference charts which indicate the range and variety of Airco regulators. A cross-referenced, illustrated layout—in which all regulators are classified according to use—provides a convenient way of finding information in the catalog.

For your free copy, circle No. 57 on Reader Information Card.

Liquid Cooling Pamphlet

A new pamphlet, "The Use of Water Cooling for Welding Equipment," will be sent to you free, upon request, from Bernard Welding Equipment Co., 10232 Ave. N, Chicago 17, Ill.

This new, easy-to-read pamphlet thoroughly covers the use, advantages and problems of water cooling encountered in various welding processes and deals primarily with three types of cooling systems; the use of

city water (municipally supplied or wells), central cooling systems, and individual "Self-Contained" coolant systems.

Besides recommending methods of cooling for (tungsten-inert-gas) welding, gas-shielded semi-automatic welding, cutting applications, automatic arc welding, resistance welding and miscellaneous processes, the pamphlet answers technical problems, such as cable voltage drop, coolant flow rates and pressures.

For your free copy, circle No. 58 on Reader Information Card.

Electronic Information Searching

A free, 8-page brochure describes American Society for Metals' new electronic system of searching technical articles, documents and patents on metals and related subjects for specific mention of any aspect of the subject. Discusses the mechanized way to reduce research costs and "time lag" between conception of an idea and production of the finished product. Shows how subscribers may receive, every two weeks, information on anything published during the preceding two weeks on their field of interest. Explains use of new GE-225 "electronic librarian" that searches through technical articles at the rate of thousands per hour.

For your free copy, circle No. 59 on Reader Information Card.

Silver Brazing Data

A new data file, detailing procedures for torch brazing with Silvaloy low-temperature silver brazing alloys, has been published by the American Platinum and Silver Division of Engelhard Industries, Inc., 75 Austin St., Newark, N. J.

The literature describes six steps for strong, leak-proof joints: joint design, preparation for brazing, fluxing and assembling, heating and making the braze, cooling the work and flux removal and inspection.

Torch brazing with Silvaloy is used in many industries, including automotive, aircraft, naval, chemical, electronic, plumbing, refrigeration and jewelry.

For your free copy, circle No. 60 on Reader Information Card.

New Concepts in Steel Design, Engineering

Four papers which discuss continuing advances in the strength levels, product forms and design applications of constructional steels are printed in a 59-page brochure, "New Concepts in Steel Design and Engineering," offered by U. S. Steel Corp., 525 William Penn Pl., Pittsburgh 30, Pa.

In sum, the papers describe and compare the types of steels that make up the modern "family" of constructional steels. Illustrations and descriptions of many actual designs and design concepts show how these steels can be used in structures and equipment to achieve higher strength, lighter weight and lower costs.

For your free copy, circle No. 61 on Reader Information Card.

Selenium Rectifiers Bulletin

The Semiconductor Division of Syntron Co., Homer City, Pa., has published a new bulletin giving electrical and mechanical specifications of its full line of certified selenium cells and stacks, and its cartridge type selenium rectifiers.

Illustrated in color, Bulletin 400 includes cutaway drawings showing features of its selenium rectifiers contributing to Syntron's exclusive semiconductor certification and guarantee policy. Details of the company's vacuum vapor deposition process are revealed in the drawings, as well as construction features of a typical Syntron selenium stack assembly and its "Selenium Slim" cartridge rectifiers.

Tables in Bulletin 400 give condensed electrical and mechanical specifications of Syntron's selenium rectifiers, while typical operating characteristics are shown in curves displaying forward current rating levels and derating curves for raised ambient temperatures.

For your free copy, circle No. 62 on Reader Information Card.

Electronic Tracer Booklet

Simple pencil line sketches of intricate shapes and forms can now be used to guide oxygen shape-cutting machines with an electronic tracer described in a new booklet (Form 55,043) now available from Linde Co., Division of Union Carbide Corp., 270 Park Ave., New York 17, N. Y. The booklet illustrates how a unique built-in kerf compensator makes it possible to reproduce one or thousands of complicated metal parts easily and with extreme accuracy from exact size drawings. Kerf adjustment represents a radical improvement over existing types of tracing units. Parts can be reproduced without the necessity of making allowance for kerf width on the drawing. Tracing accuracy is excellent, and intricate metal shapes and small holes that cannot be cut using present mechanical type tracing heads can be cut easily with the new unit.

Known as the Linde photocell tracer, the new unit eliminates the need for expensive metal or plastic templets, photographic negatives, or complicate and costly silhouettes. And there is no need to make allowance for kerf width on drawings. Drawings of parts are made in the exact size of the part desired. The kerf compensator dial is then set for the plate thickness being cut and automatically compensates for kerf width so that reproduced parts are exactly the same size as the line drawing.

For your free copy, circle No. 63 on Reader Information Card.

Pipe Welding Brochure

A new four-page brochure has just been released by Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y. on its latest welding development—the Aircomatic Pipe Welder.

The new automatic welder—using the Aircomatic (gas metal-arc) CO_2 welding process—brings production speed to pipe line welding without the need of pipe rotation. All phases of weld completion, from joint preparation to the finished weld, are accomplished by one simple set-up.

Liberally illustrated, the brochure covers all the salient features of the new Airco development: how the process works, the practical advantages and the equipment required. A full page of photographs, showing the unit in test operations in the Odessa oil field of West Texas, will be of particular interest.

For your free copy, circle No. 64 on Reader Information Card.

Welding Handbook

"Handbook for Welding Low Alloy High Tensile Steels" is a 64-page reference published by Alloy Rods Co., P. O. Box 1828, York, Pa.

The increased use and advantages of low alloy high tensile steels in the fields of structural and fabricated products has created a demand for information on the welding of such steels. Alloy Rods Co., with the cooperation of every major steel producer, has compiled a reference guide for the fabricator.

The handbook contains pertinent information on most types of commercially available low alloy high tensile "trade name" steels, including chemical analyses and physical properties of these steels, as provided by the producers.

Electrode recommendations are

given for welding each of the "trade name" steels shown as well as for hundreds of steels produced to ASTM Specifications.

For your free copy, circle No. 65 on Reader Information Card.

Alloy Data Bulletin

Forty-two of its popular specification bronzes plus heat treated variations are described in a bulletin (G-61) published by Ampco Metal, Inc., Box 2004, Milwaukee 1, Wis.

The alloys, produced by the Milwaukee firm under its trade mark AMPCOLOY, are classified in eleven basic categories. These include, for example, commercial aluminum bronzes, tin bronzes, manganese bronzes and high conductivity alloys.

This 12-page, illustrated bulletin lists nominal chemical and average physical properties, available forms, Government and Society specifications which the alloys meet and some typical applications.

Brief descriptions of Ampco's quality control laboratories, production facilities and inspection equipment are also included.

For your free copy, circle No. 66 on Reader Information Card.

Analytical Instruments Catalog

A new 28-page catalog titled "Norelco X-ray Analytical Instrumentation," containing specifications and operating data on seven key instruments for research and production control, is available from Phillips Electronic Instruments, 750 South Fulton Ave., Mount Vernon, N. Y.

The booklet describes electron probe micro-analyzers, automatic X-ray spectrographs, 100 kilovolt constant potential X-ray spectrographs, portable X-ray spectrometers, standard vacuum X-ray spectographs, X-ray diffractometers, X-ray diffraction units and cameras.

The text illustrates applications in the fields of atomic energy, chemicals, electronics, medicine, metallurgy, mining, petroleum, plastics, customs inspection, rubber agriculture, live stock feed, and railroads.

In addition to the seven major instruments, the brochure provides details on many accessory pieces of equipment including illuminators and film measuring devices, film punches and cutters, several different diffraction cameras, pole figure and high temperature attachments, wide-range goniometers and a variety of specimen holders and assemblies for air, helium or vacuum in the X-ray path.

One section deals with Geiger, scintillation, proportional and flow proportional detectors and shows the range of elements from magnesium (#12) through californium (#98) handled by the four units.

For your free copy, circle No. 67 on Reader Information Card.

Ultrasonic Welding Reprint

The Office of Technical Services of the Department of Commerce, Washington 25, D. C., recently announced the availability of a new pamphlet entitled, "Ultrasonic Welding of Structural Aluminum Alloys" and bears the No. PD 131680. This report is a reprint of an original document resulting from government-sponsored research.

The price per copy is $2.25 and can be obtained directly from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Time Meter Bulletin

"General Electric Time Meters —GEZ-3354," four pages, describes the latest addition to G.E.'s line of big look panel instruments—the Type 236 Elapsed Time Meter. Information relating to applications, features, specifications, standard ratings and schematics are also included in the bulletin.

For your free copy, circle No. 68 on Reader Information Card.

Heavy-Duty Electrode Holders

Bulletin No. 1438-HD covering Tweco Products, Inc., P. O. Box 666, Wichita 1, Kan., new No. A-14-HD Electrode Holder for 400 amp work and No. A-38-HD Electrode Holder for 500 amp work is now available. These new holders were especially designed for high amperage on large electrodes or on iron powder coated electrodes.

Both holders are a long type, fully insulated copper alloy. Two large ball-point screws attach the cable to the holder. Every cable strand is put under high pressure for maximum electrical conductivity. This efficient connection also dissipates thermal heat from the holder leaving a cool running handle. Cable connection can be made in 2 min.

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For details, circle No. 19 on Reader Information Card

Liquid Cylinder Brochure

A four-page brochure, featuring the storage and supply advantages of the new Airco AR3 Liquid Cylinder for industrial gases, is now available from Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y.

Entitled "Improved Gas Supply with the AR3 Liquid Cylinder," the brochure points out how the relatively lightweight AR3 cylinder is ideal where large mobile volumes of oxygen, nitrogen or argon are demanded. A detailed specification table presents all the pertinent data on the AR3 cylinder.

For your free copy, circle No. 70 on Reader Information Card.

Automatic Roller, Idler Rebuilder

Data on a completely automatic machine designed for hard-metal resurfacing of tractor, crane or shovel rollers, idlers and wheels, are contained in a new bulletin (MI-402) issued by Automatic Welding Co., 1005 Liberty Ave., Pittsburgh 22, Pa.

Designated as the Dual Head Micro-Matic, this machine will accept rollers, idlers and wheels up to 40-in. in diameter.

The bulletin includes both photographs and descriptions of the construction and operational features of the machine. Highlighted are such features as The Lazy Susan Rotating Table, for holding rollers, and loading them into welding station, and a Balanced Yoke which can be titled for best work position.

The bulletin also contains a convenient reference chart of Hard Surfacing Wires—their grade, weld analysis, and typical applications.

For your free copy, circle No. 71 on Reader Information Card.

Welding Fume Collectors

Bulletin No. 37-G on Welding Fume Collectors is available from Ruemelin Manufacturing Co., 3860 N. Palmer St., Milwaukee 12, Wis. The 4-page publication describes use of fume collectors and has illustrations of available equipment.

For your free copy, circle No. 72 on Reader Information Card.

Oxyacetylene Equipment Line

A new, 24-page completely revised and illustrated pocket edition of the MECO line of oxyacetylene welding and cutting equipment and allied soldering-brazing equipment is available from Modern Engineering Co., 3411 Pine Blvd., St. Louis 3, Mo.

For your free copy, circle No. 73 on Reader Information Card.

(Foreign book reviews are by G. E. Claussen, contributor to the World Wide Welding News column.)

Steel and Welding Techniques for Building Thick Reactor Vessels, (Aciiers et Techniques de Soudure pour la Construction des Cuves de Reacteurs en fortes Epaissuers), by P. E. Lagasse, M. Hofmans and R. Salkin, 195 pp. Published June 1960 by Centre National de Recherches Métallurgiques, Brussels, Belgium.

This mimeographed bibliographic study was sponsored by Euratom and consists of abstracts of 230 articles on reactor steels and welding techniques. The purpose of the review was to understand all phases of the problem, but no attempt was made to summarize the information in the abstracts.

West German Welding

Modern Welding (Neuzeitliche Schweisstechnik), 86 pp., published by Deutscher Verlag für Schweisstechnik, Duesseldorf, West Germany, 1960.

This volume contains 12 papers delivered at the annual convention of the West German Welding Society, May 17–20, 1960. It is No. 20 in the series of books on welding sponsored by the Society.

Papers included in the book are: (1) Personnel and Works Management; (2) Developments in Shrinkage Stress Research, by K. Klöppel; (3) Automatic Vertical Welding of Thick Steel Sections; (4) Consumable Electrode Welding of Thin Sheet; (5) Welding in Motor Car Manufacture; (6) Accuracy in Flame Cutting; (7) Selection of Power Sources for Arc Welding; (8) Welding and Brazing Nodular Cast Iron; (9) Gas Pressure Welding; (10) Selection of Welding Electrodes; (11) Flame Straightening and (12) Fire Prevention in Welding.

Welding Design

Responsible Welded Design (Lastechnisch Verantwoord Construeren), by H. G. Geerlings, W. P. Kerkhof and G. Zoethout. 190 pp., published in 1960 by De Technische Uitgeverij H. Stam N. V., Haarlem, Netherlands. Price: 13.75 florins.

The book was written as a test for courses in welded design offered in many cities in Holland by the Netherlands Welding Society. The first 50 pages discuss steel analysis, mechanical testing and weldability. The next 90 pages discuss stress distribution, stress concentration and brittle fracture. The remainder of the book describes welding processes and distortion. The book is intended to bring designers up to date on welding rather than to make designers out of welding engineers. The book is written in the Dutch language.

Weld Analysis

Distortion, Internal Stresses and Cracks in Welds (Schrumpfungen, Spannungen und Risse beim Schweissen), by R. Malisius. 130 pp., published by Deutscher Verlag für Schweisstechnik, Duesseldorf, West Germany, 1960. Price DM 14.80.

This is the second revised edition of a German book summarizing results obtained from the literature and by the author, who has been active in the field of distortion and shrinkage stresses for many years. After an introductory chapter on properties of materials, the author summarizes what is known about longitudinal, transverse and angular distortion by tacking, sequence and wedges. Numerical aids are given for flame straightening. Shrinkage stresses also are discussed from the standpoint of experimental results. Cracking is discussed in 15 pages, including methods of detection.

Structural Design

Design of Welded Structures (Schweisstechnische Gestaltung im Stahlbau), by P. Sahmel and H. J. Veit. 56 ppl, published by Deutscher Verlag für Schweisstechnik, Deusseldorf, West Germany, 1960. Price: DM 7.30.

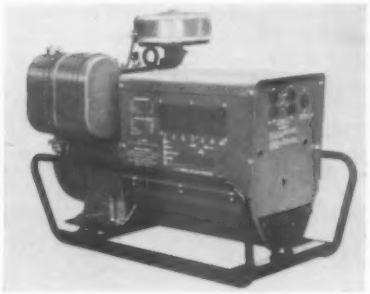
This is the second revised edition of a German book published originally in 1957. The second edition covers the same ground as the first, but the illustrations—there are 186—are with the text instead of in an appendix. The book is intended to familiarize the welding engineer and designer with flow of stress, stress distribution and notch effect in welded structures. It is an excellent nonmathematical introduction to welded structures. Particular attention is given to plate girders and column connection. This is No. 12 in the series of welding books sponsored by the West German Welding Society.

New Products

Small Electric-Arc Welding Machine

Miller Electric Mfg. Co. of Appleton, Wis., recently announced the "Memco Bantam" —a smaller version of their popular AEA-200-L gasoline engine driven welder/power plant.

The Memco Bantam's 12.3 hp single cylinder Kohler air-cooled



engine drives a rotating field generator to produce 180 amp of a-c welding power in a 100% duty cycle; 3.5 kw of 115 v 60-cycle, single-phase power, 1 kw of 115 v d-c power while welding.

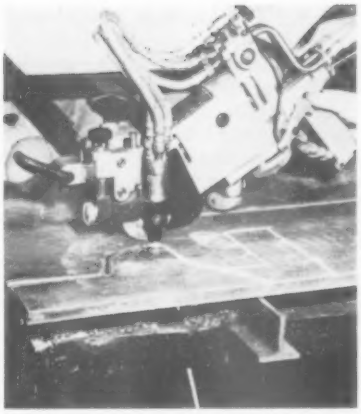
For outstanding three-way economies in original cost, weight and operation, Miller Electric claims their Memco Bantam justifies the inspection of everyone needing this type of combination welder/power plant/pipe thawer.

For details, circle No. 101 on Reader Information Card.

Flame-cutting Machine

A new 19 lb flame-cutting machine, the Linde CM-75 "Cadet", has been introduced by Linde Co., Division of Union Carbide Corp., 270 Park Ave., New York 17, N. Y. Fast, clean cuts in metals ranging in thickness from light gage sheet to 2-in. thick can be made with the new "Cadet." It is the only machine of its type or size equipped with a clutch. This allows instantaneous free-wheeling control, making it suitable for hand guided contour cutting.

Less than 19 lb complete with torch, the new Linde CM-75 "Cadet" is reportedly the lightest oxygen cutting machine on the market. It can be carried easily



from job to job. In addition to its complete portability, the new machine is claimed to be extremely versatile. Variety of jobs including straight-line cutting, bevel-cutting, circle-cutting and some contour-cutting can be handled by the "Cadet." It operates at speeds up to 30 ipm and can be used with acetylene, propane or natural gas. It handles practically all of the requirements of a small metalworking shop and is an ideal supplement to stationary shape-cutting machines in larger plants.

For details, circle No. 102 on Reader Information Card.

Thin-Gage Welding System

A new concept in welding thin gage materials has been announced by Westinghouse Electric Corp., Buffalo 5, N. Y.

Called the Westing-Arc SA-200 system, the new welding package

includes a 200 amp silicon diode rectifier power source, a compact wire drive system with wide feed range, and a new concept in straight-through torches.

The power source, a Westing-Arc Type RCV welder, has features that reportedly make it exceptionally well fitted for fine electrode wire production welding of thinner gage metals.

The new wire drive system has a range of 90 to 424 ipm with standard gearing, and can be modified to provide speeds up to 1170 ipm. Both drive rolls operate to provide more positive drive feed. A micrometer assures wire feed control adjustments heretofore impossible, it is claimed.

The straight-through torch is the lightest, coolest and most easily maneuvered welding tool on the market today, Westinghouse engineers assert. The weight of the torch itself is 22 oz, and will accommodate wire sizes in mild steel or stainless from 0.025 to 0.047 in. This Westinghouse development speeds up welding in awkward positions by keeping the handle and mounted switch in the most comfortable position. The torch is rated 100% duty cycle at 200 amp. With the torch comes a 15-ft welding cable, gas hose and electric control cable.

The wire drive system and straight-through torch can each be purchased separately and present equipment modified to make use of the new developments.

For details, circle No. 103 on Reader Information Card.

Electrode for All-Position Welding of Steel

A completely new E7018 iron powder, low-hydrogen-type electrode for all position welding of steel is now available from Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y. Called Airco Easyarc 328, the new electrode conforms to military specifications, MIL-22200 (ships).

Through use of a balanced coating, Airco Easyarc 328 provides fast and efficient metal transfer in the welding of low alloy high strength steel, mild steel, hardenable steel, high carbon steel, high sulfur steel and enameling steel. It can be used with either alternating or direct current, reverse polarity. Deposits of excellent quality and outstanding impact strength are obtainable with this electrode.

The Airco Easyarc 328 features high speed deposition, low spatter and easy slag removal. It is avail-

able in 14 in. lengths and in 3/32, 1/8, 5/32 and 3/16 in. diam.

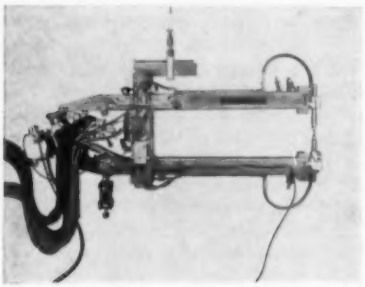
For horizontal and flat frontal welding of single pass fillets or butt welds, Airco also makes available the Easyarc 328-C. This low hydrogen type electrode features excellent usability in production of large horizontal fillets, easy slag removal and smooth appearance. The Easyarc 328-C is available in 18 in. lengths and in diameters of 7/32, 1/4 and 5/16 in.

For details, circle No. 104 on Reader Information Card.

Three-Phase Welding Gun For Stainless Steel Alloys

A special, three-phase, portable welding gun with a five-ft throat depth, equipped with interchangeable components for both spot welding and roll spot seam welding of stainless steel alloys, is now being produced by Progressive Welder and Machine Co., 915 Oakland Ave., Pontiac, Mich.

According to William B. Payne, Progressive Welder sales manager, this versatile welding gun is the first three-phase gun of its type to be used by the aircraft and missile industries



in the welding of new alloys, such as Rene 235 and various types of stainless steel, and it has unlimited possibilities for use in other fields.

The gun will handle stainless steel alloy work thicknesses from 0.001 to 0.125 in. Utilizing a special three-phase pulse counting control, it easily meets Air Force specifications for both spot welding and roll spot seam welding.

A dual system of cylinders and linkages enables the gun to weld over a broad range of materials. The follow-up, required in certified resistance welding, is built out at the end of the gun, where electrode force is required. Its calibrated die spring arrangement assures accurate control and positive vertical tip alignment.

The throat height of Progressive's new welding gun is 18 in., and it will attain a maximum forge pressure of 4000 lb.

For details, circle No. 105 on Reader Information Card.

Automatic Flash Welder

To meet severe strength and anneal criteria in welding high speed, metal cutting saw blades of tungsten or molybdenum, Thomson Electric Welder Co., 161 Pleasant St., Lynn, Mass., has designed a compact 4 kva automatic flash welding unit that features adjustable work clamps, an integral annealing system and the company's patented synchromatic mechanism. According to the manufacturer, extensive laboratory tests and a number of in-plant applications reveal that the flash welds made in the equipment withstand the flexing cycles commensurate to or better than the parent material.

The machine, bearing a model F-00 designation, is bench-mounted and measures about 21-in. high by 28-in. wide and 15-in. deep. The 4 kva water-cooled transformer mounts in the frame, affords a tap selection of eight points of heat.

For details, circle No. 106 on Reader Information Card.

New Alloy Flux

Lincoln Electric Co., Cleveland, Ohio, has announced a new agglomerated alloy flux for submerged arc fabricating or rebuilding 12–15% manganese steel parts. The development of Lincolnweld M-210 flux, the company states, offers maintenance cost economies in surfacing or reclaiming manganese or carbon steel parts by reducing material costs and increasing deposition rates and welding speeds. These same performance features can reduce production costs and further expand the use of composite design in original equipment manufacture, the company claims.

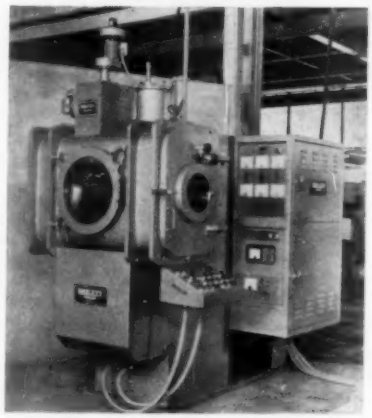
Physical properties of weld metal deposits produced with Lincolnweld M-210 flux demonstrate a yield strength of 64,400 psi, an ultimate strength of 107,500 psi, and an elongation in 2 in. of 35 per cent. Typical deposition rates of semi or full automatic single electrode submerged arc welding equipment at a 350 amp dc setting is 16.2 lb of weld metal per hour at a 100% operating factor (arc time per cent of welding time). Where application justifies the use of twinarc submerged arc welding equipment, the deposition rate can be increased to 47.0 lb of weld metal per hour at 900 amp dc and a 100% operating factor. In addition, the medium carbon, nickel manganese steel deposit is less subject to carbide percipitation during cooling than high alloy "Hadfield" manganese steel thereby simplifying welding procedures.

As welded all weld metal deposits have a hardness value of 11-19 Rockwell C and can be machined. Being austenitic, this deposit has the ability to surface work hardened in service and will develop a surface hardness ranging from 48 to 53 Rockwell C while the rest of the deposit remains soft and tough. For this reason, practical maintenance applications for the product include rebuilding worn surfaces prior to application of highly abrasive resistant materials or surfacing where the deposit itself is subject to wear.

For details, circle No. 107 on Reader Information Card.

Electron Beam Welding Machine

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., has announced their newest design of electron beam welder, Model VX-20-30-48. The unit is presently in operation within the company's welding laboratory facilities, where it is used in the welding of various refractory and reactionary metals as well as dissimilar groupings.



The vacuum chamber measures 20-in. wide by 30-in. high by 48-in. long. This rectangular design, first used by Sciaky, affords maximum geometrical spaces. Complete gun mobility takes full advantage of the internal chamber dimensions.

The electron gun is provided with traverse motion (Y axis) and vertical motion (Z axis) powered by Sciaky's own speed and position servo-control. This control (trade name of Sciakydyne) also effects longitudinal motion (X axis) to the internal work table. Numerical control is easily adapted to the Sciakydyne Control concept.

The vacuum chamber is pumped to 1 x 10^{-4} mm. Hg in about four minutes. The pumping sequence is fully automatic. With atmosphere conditions equal, both end doors

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For details, circle No. 28 on Reader Information Card

can be opened. Also, the 20 in. diam front port opens to provide closer accessibility to the electron gun and work area.

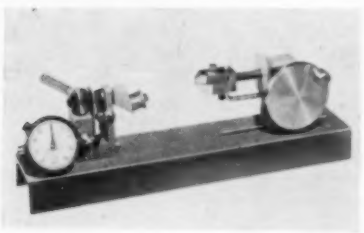
An electron beam of 350 milliamp at 30 kv can be produced by the electron gun and associated power supply. The beam spot can be focused into a 0.030-in. min. diam and over 1.0-in. diam max.

Recently, this low voltage system successfully welded $1^3/_4$-in. aluminum plate with depth to width ratio of 22-1. Typical weld settings for various alloys are listed in Sciaky Bulletin No. 344.

For details, circle No. 108 on Reader Information Card.

Lightweight Tensile Tester

A new portable tensile tester weighing only $6^1/_2$ lb is now available from Detroit Testing Machine Co., 9390 Grinnell Ave., Detroit 13, Mich. The Model VTA tensile tester is available in 50 and 100-lb load capacity versions and sells for much less than conventional portable tensile testers. Designed for



field and sales work, the new machine provides accurate tensile strength data for small gage wire, spot weld coupons, rope, string, fishing line and textile materials. Overall length of the new model is 15 in.; height, 6 in.; weight, $6^1/_2$ lb. Minimum length of test specimens is $^1/_2$ in., maximum 8 in. The indicator needle locks at a maximum load, and has push-button release.

For details, circle No. 109 on Reader Information Card.

Reverse-Flow Check Valves

Harris Calorific Co., 5501 Cass Ave., Cleveland 2, Ohio, has announced a new group of reverse flow check valves that fit all makes of torches, line regulators and cylinder regulators. These safety check valves stop dangerous contamination of oxygen regulators by fuel gas and prevent oxygen from entering the gas regulator. Torch models prevent the gases from mixing in the hoses, a common cause of explosions and fires.

Harris states that these check valves have such a low cracking pressure that new operational safety is reached. While they eliminate a major hazard, the valves open to full flow with practically no effort or restriction. The new check valves can be used on torches with low pressures of less than 1 lb acetylene or 3 oz natural gas. They operate with all commerical gases.

For details, circle No. 110 on Reader Information Card.

Component Packaging Welding Accessories

Keyed particularly to the needs of production-line component packaging is a new line of precision welding accessories developed for use with Model 1032 Minature Welding Head and other equipment, made by Weldmatic Division/Unitek Corp., 950 Royal Oaks Dr., Monrovia, Calif. Advantages of specialized accessories include reduced eyestrain and operator fatigue, clear and uncluttered working area, and increased reliability of production modules.

For details, circle No. 111 on Reader Information Card.

Low-Hydrogen Iron-powder Electrode

A new improved AWS class E-7018 low-hydrogen iron-powder electrode for use in all positions with ac or dc reverse polarity welding has been added to the Murex electrode line of Metal & Thermit Corp., Rahway, N. J. The complete line includes more than 1000 types and sizes.

Designated Speedex HTS, the new electrode was developed to improve physical and mechanical properties, arc stability and weld contour offered by previous electrodes in this class. Deposits meet MIL Specification E-22200/1 for low-hydrogen iron-powder electrodes.

Speedex HTS electrodes may be used in flat, vertical and overhead positions. Typical applications include joining such materials as low alloy high strength steels, hardenable steels, high carbon steels, high sulphur steels and enameling steels. The electrodes are well suited for all-position welding of industrial piping and welding of restrained joints in thick sections of mild steel.

For details, circle No. 112 on Reader Information Card.

Oxy-Fuel Gas Gouging Nozzles

Two-piece gouging nozzles designed for use with natural gas and propane have been introduced by Linde Co., Division of Union Carbide Corp. 270 Park Ave., New York 17, N. Y. Producing greater

preheat than heretofore possible using natural gas or propane, these new gouging nozzles satisfy a long standing demand. They are ideal for gouging heavily-scaled or rusted plate, or castings with sand incrustations.

Design of the new nozzle, designated the Oxweld 1542 Series, incorporates a slotted internal nozzle with an external sleeve. Slotted design provides greater number of individual small flames with highest gas velocity which combine to produce a high-intensity flame. Excellent stability prevents the high velocity preheat flames from blowing off. Gouging starts have been obtained in 4 sec with the new Oxweld nozzles.

For details, circle No. 113 on Reader Information Card.

New Method for Joining Honeycomb Sections

A new method for brazing and soldering honeycomb sections has been announced by Murray Hill Research, P. O. Box 73, Murray Hill, N. J. This process drastically reduces costs through the use of a noncorrosive flux, eliminating the need for atmospheres, vacuum, long heating and cooling cycles, it is reported. Honeycomb sections of ferrous or nonferrous metals can be joined with a variety of brazing alloys or solders using optional heating methods and equipment.

For details, circle No. 114 on Reader Information Card.

Compact X-ray Film Container-Transporter

A versatile new darkroom-to-equipment area X-ray film carrier that prevents fogged and crimped edge films has been introduced by the Ansco Division of General Aniline and Film Corp., Binghamton, N. Y. Called the Ansco-Tainer, it is light-tight, lightweight, has a durable long-wearing stain resistant plastic finish.

Each Ansco-Tainer will hold a complete 75-sheet interleaved or 150 sheet non-interleaved Pouchpak from an Ansco Superpak or Bulkpak film carton. In addition to lower cost and portability, the Ansco-Tainer offers convenient darkroom handling with a light-sealed cover that opens and closes with ease in the dark.

Principal uses for the Ansco-Tainer are as a container for unexposed film; a container to take film to an outside job; a carrying case for film between loading and processing rooms; storage of processed, but uninterpreted film.

For details, circle No. 115 on Reader Information Card.

Deoxidized Copper Spools

All-State Welding Alloys Co., Inc., White Plains, N. Y., announces the addition of ultra-high-quality deoxidized copper to the famous layer-level wound Spoolarc metals for inert-gas metal-arc welding applications. Deoxidized copper is one of four new copper and bronze alloys to be introduced by All-State in 1961.

This precision spooled copper can be used for joining copper to mild steel or to copper and bronze alloys, for copper bus bars, including heavy sections. It is free-flowing and produces strong ductile welds which maintain a relatively high electrical conductivity rating. As an overlay, deoxidized copper is being used on rocket projectiles, artillery shells, heavy duty compressor pumps and on bronze valve castings.

For details, circle No. 116 on Reader Information Card.

Gold-Coated Welding Plate

A new high-quality gold-coated welding plate has been developed by the American Optical Company's Safety Products Division, Southbridge, Mass. Use of this plate, called "Weld-Cool," gives increased visibility of the welding operation, reportedly resulting in better welds.

This premium-type protective glass filter is particularly adapted to gas-shielded welding arc pro-

REPAIR and REBUILD
WORN BUCKET PARTS
THIS ECONOMICAL WAY

- Manganal has the greatest toughness, with work-hardened abrasion resistance, of any steel. Protects profits by keeping equipment producing longer . . . with less cost than new parts.

WORN HEAVY-DUTY EQUIPMENT PARTS REQUIRE . . .
HEAVY-DUTY
MANGANAL®
11%-13½% MANGANESE-NICKEL STEEL
ABSORBS IMPACT AND ABRASIVE WEAR LONGER THAN NEW PARTS

BUCKET DOOR-flame cut from Manganal Hot Rolled Plate.
BUCKET DOOR LATCH PIN — cut from Manganal Square Bar.
BUCKET DOOR LATCH PIN BRACKETS — form from Manganal Flat Bars.
BUCKET SIDES — cut from Manganal Flat Bars.
BUCKET CUTTING EDGE FOR WORN LIP — bend from Manganal Hot Rolled Wedge Bar.
BUCKET TOOTH SOCKETS—reinforce with Manganal Round Bars.
BUCKET CUTTING EDGES BETWEEN TEETH — cut from Manganal Hot Rolled Wedge Bars.
BUCKET FLOOR LINER — flame cut and bend from Manganal Hot Rolled Plate.
BUCKET HITCH PINS & HINGE PINS — cut from Manganal Round Bars.
CRACKED BUCKET LIP—repair with Manganal Electrodes for extra strength.
BUCKET HEEL — reinforce with Manganal Flat Bars.
BUCKET TAPERED LIP—form from various thicknesses of Manganal Round Bars.
BUCKET TEETH — repoint with Manganal Wedge Bars.

Available from all welding distributors.
Nearest Distributor Upon Request. Send for Helpful Literature.
STULZ-SICKLES CO.
929 Julia Street • Elizabeth, New Jersey

For details, circle No. 21 on Reader Information Card

LINDE ELECTRIC WELDING

PLASMARC

FIRST PROCESS FOR FUSED DEPOSITS (.010-IN. AND UP) WITH CONTROLLED DILUTION AT HIGH SPEEDS

SEE IT "LIVE" AT THE 43RD NATIONAL METAL SHOW COBO HALL, DETROIT OCT. 23-27, BOOTH 127

For details, circle No. 22 on Reader Information Card

cesses where excessive infrared radiation is present. It provides new visible light transmission in the blue region of the spectrum and absorbs the yellow flare associated with certain welding processes. The new welding plate also provides the welder with cooler, more comfortable and efficient protection, the company asserts.

The plate is available in shades 10 and 12. They come in standard plate size 2 by 4 1/4 in.

For details, circle No. 117 on Reader Information Card.

Single-Phase Welding Power Supply

Now in production following 1 1/2 years of development and field testing, a 200 amp dc constant voltage power supply for metallic inert-gas-arc welding to operate on single-phase lines is available from Glenn Pacific Corp., 3703 37th Ave., Oakland 1, Calif.

Special Glenn circuitry (patent pending) provides characteristics ideally suited to steel, aluminum or alloy inert gas metal arc welding,

including the entire "short arc" range and the lower end of the "spray arc" range.

Designated the Model CV200, the unit has a rated output of 200 amp at 35 vdc, 100% duty cycle. Open circuit output voltage range is 8.5 to 53 vdc on 230/460 v input.

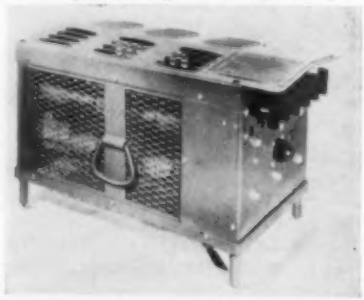
Low input requirements (17 amp at 460 v or 34 at 230, rated load) mean inexpensive installation. Operation is extremely simple; operator merely presets the desired voltage.

For details, circle No. 118 on Reader Information Card.

Control Resistors for Multi-Arc Welding

A new series of single-operator "Weldline" welding resistor stations for multi-arc welding systems, in square housings that facilitate stacking is being offered by J. B. Nottingham & Co., Inc., 441 Lexington Ave., New York 17, N. Y.

The resistor stations permit individual welder control of current form a multi-arc source in five- or ten-ampere steps. Designed pri-



marily for dc metallic arc welding, the stations can also be used for gas shielded tungsten arc, consumable electrode, and other processes.

Compact design and light weight, with large carrying handles, contribute to the units' portability. Those rated from 235 to 310 amp measure 12 1/2 x 21 1/2 x 14 3/4-in., while the 315 and 400 amp units measure 15 1/4 x 24 1/4 x 14 3/4-in. Weights range from 53 to 64 lb, depending on rating.

For details, circle No. 120 on Reader Information Card.

All-Position Welding Machine

New arc welding equipment for use in a variety of difficult fabrication and reclamation jobs, features very-small-diameter electrode wire and employs inexpensive carbon dioxide or gas mixtures, it is announced by National Cylinder Gas Division, Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

The semi-automatic "MiniArc" equipment welds light-gage metals in any position, is fast in operation and eliminates much clean-up time because it reduces spatter, according to NCG.

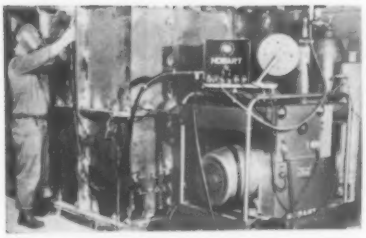
MiniArc equipment consists of an AM-8 torch, WC-5 control with wire drive, interconnecting gas and flexible conduit assemblies. The unit, only 12 1/4 by 16 by 20 in., has a wire feed rate from 55 to 500 ipm. Wire sizes are 0.025, 0.030 and 0.035 in. In addition to using carbon dioxide and argon-carbon-dioxide mixtures, it can use argon and helium for welding alloys.

For details, circle No. 119 on Reader Information Card.

Multiple Welding Machine

Metal fabricators using more than one of the new semi-automatic welding processes are simplifying operations and reducing capital equipment investment at the same time with the new "Multi-Wire" welding package, according to Hobart Brothers Co., Troy, Ohio.

The "Multi-Wire" welder is a combination welder and matched wire feeder which will utilize all of the new semi-automatic processes. A

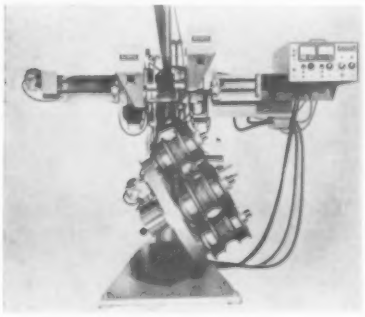


family of welding guns has been developed for each of these processes. The proper welding gun and cable assembly with the appropriate drive rolls and wire guides makes the machine immediately available for a specific welding process. When changing from one process to another, it is merely necessary to attach the appropriate gun and cable assembly, and install the appropriate drive rolls and wire guides. When welding aluminum or utilizing other processes where water cooling is necessary for the gun, the water cooling tower is brought into operation. In a matter of minutes the "Multi-Wire" welder can make the change from one process employing one type and size of wire, to another process employing a different type and size wire. Some fabricators merely interchange complete wire feeder and gun assemblies when changing processes.

For details, circle No. 121 on Reader Information Card.

Multiple-Spindle Roller-Idler Rebuilding Machine

Stoody Co. (Box 901, Whittier, Calif.) Automatic Welding Systems Model MR is a quality multi-spindle rebuilding unit; it is the only roller-idler machine with offset



main spindle support arm providing minimum head adjustment from tread to flange. Other operating features include a columnized, easy-to-operate electronic control panel; full welding heads; wire straighteners; maintenance-free flux valves and shutoff mechanisms; and a rugged carriage assembly that is engaged for directional travel by a simple 3-position lever. This unit can be used with layer wound coils or economical 500-lb Payoffpaks. System includes two 500 amp constant voltage, 100% duty cycle power sources.

For details, circle No. 122 on Reader Information Card.

Groove-Joint Pliers

The line of spark-resistant groove-joint pliers produced by Ampco Metal, Inc., Box 2004, Milwaukee 1, Wis., has been expanded to four sizes with the addition of 16-in. long, 4-in. capacity and $6^1/_2$-in. long, 1-in. capacity models.

The pliers are forged from alloys approved for nonsparking use in Department of Commerce report PB-151650. This approval is not granted to steel tools.

Like all Ampco Safety Tools, the groove-joint pliers are also noncorrosive and nonmagnetic. They are especially suitable for marine, aircraft, general industrial and automotive use.

Groove-joint construction provides five nonslip parallel openings which greatly increase the pliers' usefulness. Unusually long handles supply needed leverage when maximum gripping is required.

The tools meet MIL specifications and are approved by Factory Mutual Laboratories for use in locations where explosive or flammable conditions are encountered.

For details, circle No. 123 on Reader Information Card.

Welding, Cutting Outfit

The Harris Calorific Co., 5501 Cass Ave., Cleveland 2, Ohio, has announced a new heavy-duty welding and cutting outfit designed for shop, farm, home or school use.

Harris includes in this outfit its No. 63-F heavy-duty welding torch. It takes up to a size 22 tip (No. 24 drill orifice), has the capacity to handle a wide range of welding jobs. Also, it features high-temperature silicone "O" ring seals that permit fast, easy change of tip assemblies.

The head-mix-type cutting attachment will cut up to 6 in. and features rugged triangular tube construction. Its pre-heat valve also serves as positive oxygen shut off.

Industrial size Model 25 regulators have 5.9 sq in. diaphragms to assure accurate control of flame. They have a capacity to weld heavy jobs, cut up to 12-in. thick. Regulators' soft seat valves close with pressure.

For details, circle No. 124 on Reader Information Card.

Now you can check
WELD TIME with
new **PORTA-COUNT**
cycle counter

only **$282**

Counts actual weld time during firing. PORTA-COUNT is light and small enough to carry easily—keep right on the job. Completely portable and self-contained with long life (up to 2 years) batteries. Counts single phases.

No Plug In **No Clips** **No Clamps**

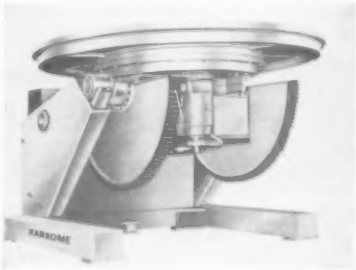
PORTA-COUNT uses an inductive pick up to count, sensing magnetic field around power line, welding buss, transformer or electrodes.

INSTRUMENT CONTROL CO.
2309 Snelling Avenue
Minneapolis 4, Minnesota

For details, circle No. 23 on Reader Information Card

80,000 Lb Capacity Positioner

Production of a new, precision designed positioner rated 80,000 lb at 20-in. center of gravity, has been announced by the Ransome Co., Scotch Plains, N. J., manufacturer



of an extensive line of welding positioning equipment. Offering versatility not available in many models of this size, the new unit features 36-in. vertical adjustment, with no column projection above the table top, even with the table in a horizontal position.

For details, circle No. 125 on Reader Information Card.

Multiple Stress Relieving, AC, DC Welding Machine

A compact, portable machine that can be used to stress relieve up to 12 welds at one time and to do AC, DC welding was formally unveiled by Otto Kreisel, its inventor, at a national sales meeting of Electric Arc, Inc., recently in Newark, N. J.

BETTER WELDING THROUGH ARCOS QUALITY CONTROL

X-ray Emission Spectrograph shows analysis of Arcos weld metal

Predictable performance of Arcos weld metal results from strict adherence to uncompromising standards. The program of rigid quality control of filler metal products enforced by Arcos is comprehensive and far-reaching. Every phase in production is subjected to constant inspection. Modern testing instruments provide highly accurate analysis of materials and weld metals. Rigid quality control assures predictable performance of Arcos filler metal products.

ARCOS

Arcos Corporation • 1500 S. 50th St. • Philadelphia 43, Pa.

For details, circle No. 24 on Reader Information Card

Two basic models of the "UniPak" are being produced, one equipped with six individual Uni-Pak resistance heating control units, and the other with three units. Both models can be used for AC, DC welding and for stress relieving—simultaneously if desired. The six-unit machine can be used to stress relieve as many as 12 welds at one time in pipe up to 3 in. in diameter, and up to six welds in 6-in. pipe. The machine's primary stress relieving applications are in treating thin-walled alloy pipe. Since resistance heating is used, maximum pipe wall thickness for programmed heating is about $^3/_8$ to $^1/_2$ in.

The UniPak is completely equipped with controlling instrumentation, a six-point recording strip chart, self-contained constant potential source supply, AC, DC convertor and welding control resistor unit. Stripped-down Uni-Paks for stress relieving only are available. Also, since the machines may be operated from any 1000 amp, 40 v current source, they are available without the self-contained constant potential source. The UniPak is designed for use with Electric Arc's HiTemp Clamp-On Resistance Heater, E.A.I. Radiant HeatKoils, or any Falcon-type high voltage resistance heater with slight modification.

Heart of the UniPak is the individual UniPak Resistance Heating Control unit, which can be removed from the machine for individual use in stress relieving or can be purchased separately. The individual unit has a maximum output of 200 amp from two 100 amp fuse circuits. It can be used for stress relieving up to 1900° F, and has cable connections for use with two resistance heaters at the same time.

For details, circle No. 126 on Reader Information Card.

Automatic Field Welding of Fixed Pipe

The automatic welding of large diameter, transmission line pipe in the field—in a fixed position (without rotating the pipe)—is now possible with an automatic welding machine developed by H. C. Price Co., in cooperation with Crose-Perrault Equipment Corp. and Hobart Brothers Co.

The machine employes the Hobart Micro-Wire Welding Process. This is a gas shielded-arc welding process using CO_2 gas, a small diameter electrode wire usually in the range of 0.035-in. to 0.045-in., a low arc voltage in the neighbor-

hood of 19 to 20 v and a relatively low welding current, usually 120 to 150 amp d-c reverse polarity. Controls for both the fixture and welding head are preset and operated by a pushbutton pendent.

Field tests on pipeline projects in Oklahoma and California have indicated the following advantages: The machine will automatically join 36-in. diam A.P.I. 5LX Grade X52 pipe of $^{4}/_{16}$-in. wall thickness in less than 8 min. The pipe is accepted as welded and no cleaning or grinding is necessary. The procedure meets A.P.I. codes for bending, X-ray, etc. Welds standard pipe without back up ring and no preparation tool is required to lead the welding head.

For details, circle No. 127 on Reader Information Card.

Protective Hose Wrapping

Electric hoses can be wrapped with "Zippertubing," a product of the Zippertubing Co., 13000 S. Broadway, Los Angeles, Calif., to help eliminate wear on the hoses and spark burns that cause irreparable damage.

Application of zippertubing is said to be very simple as it is wrapped around hoses and zipped closed (tape has a zipper slide track attached to the outer edges)

For details, circle No. 128 on Reader Information Card.

WELD WITH ARCOS FOR QUALITY WELD METAL

Arcos offers a complete line of filler metals for welding stainless, low alloy steels, mild steels, aluminum, and for hard surfacing . . . manually or automatically. Arcos covered electrodes, electrode wires, and filler rods are available for manual arc, submerged arc, inert gas, CO_2 shielded, and electroslag processes. The quality of all Arcos filler metal products, including fluxes for submerged arc welding and EB Inserts for root pass welding, is carefully controlled. *Make* sure it's Arcos . . . *be* sure of top performance.

ARCOS

Arcos Corporation • 1500 S. 50th St. • Philadelphia 43, Pa.

For details, circle No. 25 on Reader Information Card

Light Production, Maintenance Welding Machine

A record 200 amp of welding current—from a minimum of 25 to a new high of 225—is now available for light industry applications in an a-c welder just introduced by the A. O. Smith Corp. A. E. Johnson, machine sales manager of the firm's Welding Products Division, announced the new industrial welder as part of a long-range corporate program to increase the small shop and garage operator's ability to deal with difficult welding conditions, enable him to use a greater variety of electrodes, and stay abreast of the growing maintenance requirements of today's mechanization.

For details, circle No. 129 on Reader Information Card.

Natural Gas Cutting Tips

Harris Calorific Co., 5501 Cass Ave., Cleveland 2, Ohio, recently announced the addition of a new line of low pressure natural gas cutting tips which provide a wider range of flame adjustments for faster, cleaner

cutting of thin plate steel.

Identified as the Series 6290 NX, these tips are used with Harris injector-type cutting torches and cutting attachments. The new tips are available in three sizes: 6290-000NX, 00NX and ONX.

For details, circle No. 130 on Reader Information Card.

Deerskin Welding Gloves

A newly designed welding glove, made of pearl flesh split, Brazilian Jack Deerskin, has just been introduced by the Glove Div. of the Riegel Textile Corp., 260 Madison Ave., New York 16, N. Y. This leather is exceptionally soft, yet provides excellent wear and withstands heat well, it is reported. The back of the hand is lined for added insulation and perspiration absorption, and the cuff is fully lined with lightweight suede to prevent chafing. The glove has an extra-long $6\frac{1}{2}$ in. cuff for extra arm protection. An extra-large pull patch protects the threads that join the cuff and the glove to provide longer wear. In addition, another patch on the palm of the glove gives added protection to the thumb seam. Other seams are fully welted where metal flow is heaviest.

According to Riegel, both the leather and construction features make this one of the most comfortable and long-wearing gloves a welder can wear.

For details, circle No. 131 on Reader Information Card.

Compact Stud Welding Unit

An entirely new, low-cost, lightweight welding machine for fastening insulation pins or studs to ductwork, tanks, curtain wall, siding and roofing is now available to contractors from Omark Industries, Inc., 9701 S. E. McLoughlin Blvd., Portland 22, Ore.

Called the Omark Gramweld Model 7000 Insul-Pin Welder, it consists of two basic units, a compact welding cabinet weighing only 38 lb and a pistol-grip welding gun. Operating on power supplied from standard 110 v. ac. outlets, the Model 7000 welds nail-like "Insul-Pins" to steel, stainless steel or aluminum. Insulation is then impaled on the pointed pins and secured permanently with spring-metal "Insul-Clips."

Because of its low weight and suitcase size ($7 \times 10 \times 20\frac{1}{2}$ in.), the Model 7000 is easily handled on scaffolding and in cramped working quarters, according to the manufacturer.

The Omark Gramweld method enable welders to weld up to 20 pins per minute under average conditions. Insulating material may be attached immediately after welding, and long welding cables permit the operator to work an area 80 ft in diameter without moving the machine or changing electrical connections.

For details, circle No. 132 on Reader Information Card.

New Aluminum Winding Process

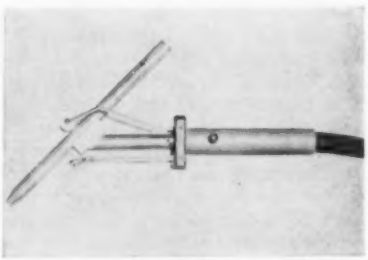
American Brazing Alloys Corp., P. O. Box 11, Pelham, N. Y., has developed a new process for producing an extremely clean and perfectly level layer wound aluminum welding wire. This new process provides the welder with a minimum of downtime and the optimum of production in aluminum welding. The aluminum welding wire will be processed in 1, 10, and 20 lb spools. Aluminum rods are also available in a multitude of alloys including 4043, 1100, 5356, 5052, 5154, 718 and others. Data sheets are available upon request.

For details, circle No. 133 on Reader Information Card.

Metal Removal Torch

Arcair Co., Lancaster, Ohio, has announced the Model "V" metal-removal torch for cutting, gouging and beveling all types of metal. It is designed primarily for pad washing in steel and alloy foundries. It will also have use in exterior fin and other sprue removal and on any heavy duty metal removal application.

The Model "V" features a spring steel wire guard surrounding the



head which prevents accidental arcing. An open-head type of construction permits good working visibility. It's light weight will permit easy handling. The air supply is controlled by a push-button type of air valve. A $\frac{3}{4}$-in. concentric cable assembly will be furnished with the torch.

The Model "V" is available in three sizes, for use with $\frac{1}{2}$-, $\frac{5}{8}$- or $\frac{3}{4}$-in. electrodes. Current requirements will vary from 400 to 1600 amp, depending on electrode size and type of work. Air pressure required is 80 psi.

For details, circle No. 134 on Reader Information Card.

Ultra-High-Voltage Capacitors

A new line of capacitors for ultra-high-voltage d-c filtering, X-ray, nuclear accelerators, betatrons, pulse networks, radar, and high voltage test equipment is announced by Corson Electric Mfg., Corp., 540 39th St., Union City, N. J. These rectangular, bakelite tubes are engineered to occupy considerably less volume than conventional cylindrical capacitors. The volume is further reduced by the triple dielectric construction which consists of a special plastic film and multi layers of thin kraft paper impregnated with an electrical grade mineral oil adding the third dielectric. Special construction eliminates Corona problems frequently as-

sociated with capacitors of this type. The capacitors are designed for dc operation at 60° C for 10,000 hr and may be used to 0° C. Nine ranges are available from 50 to 250 kv dc.

For details, circle No. 135 on Reader Information Card.

Wide-Vision Welding Helmet

A new Fiberglas Wide-vision Welding Helmet has been designed and is in production by The Fibre-Metal Products Co., Chester, Pa.

Designated No. 880, the new helmet is light in weight (22 oz complete with lens), uses lens size

$4^1/_2$ x $5^1/_4$ in. for maximum vision, and is available at low cost (approximately $11 including lens, depending on quantity). Weight and cost are equivalent to present shields, masks and helmets using the smaller 2 x $4^1/_4$ in. lens . . . yet field of vision is increased over 120%.

For details, circle No. 136 on Reader Information Card.

Multi-Wire Welder

Hobart Brothers Co., Troy, Ohio, will show and demonstrate their new multiple process semi-automatic welder, in space No. 720, at the 1961 ASM Detroit Metal Show, Cobo Hall, October 23–27.

The "Multi-Wire" is a combination welder and matched wire feeder which will utilize all the new semi-automatic welding processes. A family of welding guns has been developed for each of these processes. When changing from one process to another, it is merely necessary to attach the appropriate gun and cable assembly, and install the appropriate drive rolls and wire guides. "Micro-Wire" semi-automatic welding of thin gauge metals will also be demonstrated.

On exhibit will be the complete line of Hobart manual arc welding equipment, electrodes and accessories.

Personnel in charge of the exhibit will be John H. Headapohl, mgr. of automatic welding sales; R. K. Buchanan, territorial mgr.; Howard Cary, director of Hobart Technical School, W. B. Howell, distribution mgr.; and W. H. Hobart, Jr., assistant secretary-treasurer.

For details, circle No. 137 on Reader Information Card.

Temperature Indicator Coatings Aerosol Packed

Eight new ratings of Tempilaq° in aerosol packaging have just been added to this line of temperature indicating coatings and will be exhibited in The Space Flight Report to the Nation—sponsored by the American Rocket Society—October 9–15, 1961—at the New York Coliseum—Booth 182.

The newly developed aerosol Tempilaqs°, made by Tempil° Corp., 132 W. 22nd St., New York 11, N. Y., cover the interval 650° F to 1000° F. This makes 44 systematically spaced temperature ratings presently available in aerosol form—spanning the range 100° F to 1000° F.

The convenience of coating large surfaces by the spray can technique has made aerosol packaged Tempilaq° very popular in a number of important applications. These include non-destructive testing of honeycomb panels; monitoring the operating temperatures of reaction vessels; fabrication of massive structures; heating, preheating and stress relieving large areas.

While Tempilaqs° for temperatures above 1000° F are presently available in standard glass bottle packaging only, research is being continued to perfect aerosol packaged Tempilaq° in the higher temperature range to 2500° F.

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Hotbox Welding Electrode Moisture Stabilizer

A new Hotbox electrode moisture stabilizer prevents costly welding defects, according to W Corp., 1500 W. Third Ave., Columbus 12, Ohio. The Hotbox maintains welding electrodes at factory-specified moisture content, providing positive protection of electrodes from moisture "pick-up" right up to the moment of use. The Hotbox Moisture Control reduces surface and underbead cracking, hidden porosity, surface splatter, and hydrogen embrittlement. Thus the Hotbox eliminates many causes of improper welds, excessive cleaning, weld replacement.

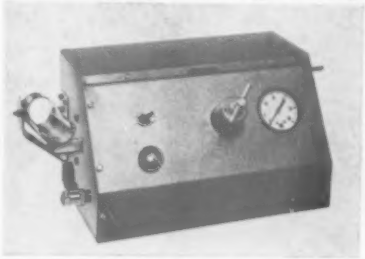
The Hotbox is constructed of heavy-gage steel plus an extra long life heating element, and carries a full one year's warranty. It is available in two sizes for 14- and 18-in. rods. The Hotbox itself is completely portable and operates from any 115 v a-c or d-c outlet in the shop and in the field.

For details, circle No. 139 on Reader Information Card.

Automatic Gas, Power Control Unit

A new automatic gas and power control unit designed to conserve costly inert gases such as nitrogen is available from Laramy Products Co., Cohasset, Mass.

The unit cuts consumption of expensive bottled gases, according to the company, so that gas is only



used when actual welding is being done. It is also said to prevent accidental burning-out of heating elements due to compressor failure or carelessness. Inert gases are used to prevent oxidation during welding of polyethylene and polypropylene plastic.

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Brass Fittings

Hand-tight pigtail assemblies, parts for hand-tight manifold assemblies, copper and stainless steel tubing for manifold assemblies, special regulator adaptors, and porous metal filter for regulator inlet nipples are new product additions to the line of more than 200 brass fittings manufactured by Western Enterprises, Inc., Bay Village, Cleveland 40, Ohio.

According to the manufacturer, oxygen pigtail assemblies are for plant or filling station use, and available in copper or stainless steel. Oxygen hand nut, plastic-tipped oxygen nipple, and replaceable plastic tips comprise the hand-tight manifold assembly parts, as well as annealed copper tubing available coiled and stainless steel tubing in random lengths. Six new regulator adaptors to CGA parts are also available. The porous metal filter is for use with "S" series regulator inlet nipples.

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SUPPLEMENT TO THE WELDING JOURNAL, OCTOBER 1961

New Method of Backing Double-Vee Weld Joints in Steel Plate

Steel shot with a thin film of baked aluminum paint proves most suitable as a granular backing material for manganese-molybdenum armor plate

BY J. N. CORDEA, R. M. EVANS AND P. J. RIEPPEL

ABSTRACT. Research was conducted to develop granular metallic backing materials for the first weld pass in double-V joints in armor plate.

Manual electrode welding was used during the evaluation of the various backing materials. Manganese-molybdenum armor plate was the base material, and the electrode was low-hydrogen MIL 230-16.

Several backing materials produced a desirable flat-to-concave underside weld contour. These were: high silica foundry sand, commercial neutral welding flux, high-carbon commercial steel shot, specially made steel shot materials coated with sodium silicate and coated with oxidized aluminum paint. The best backing material developed was a steel shot approximating the composition of welds made with the MIL 230-16 electrode and coated with a thin film of baked aluminum paint. A slightly concave underside weld contour was always produced and subsequent weld passes were easily deposited. The Charpy V-notch impact properties of welds backed with this material were generally better than those welds backed by the conventional copper bar.

Introduction

A research program to evaluate and improve welding processes for armored vehicle hulls was conducted from May 1959 to August 1960. The main purpose of this work was to develop a granular metallic backing material for the first weld pass of double-Vee joints which would improve the quality of the underside weld contour, reduce the cost of back chipping, and eliminate costly copper bar backup techniques. The need for a satisfactory backing material to compensate for poor fitup and misalignment also was considered.

The authors are with the Metals Joining Division of the Battelle Memorial Institute, Columbus, Ohio—J. N. CORDEA as Principal Welding Engineer, R. M. EVANS as Assistant Chief, and P. J. RIEPPEL as Chief.

Paper presented at the AWS 42nd Annual Meeting held in New York, N. Y., during Apr. 17–21, 1961.

Procedure to Evaluate Backing Materials

Copper is now one of the most widely used backing materials. There are, however, disadvantages in its use. The joint fitup in weldments must be held within close tolerance if the underside of the root weld pass is expected to be uniform. This is a costly, time-consuming operation, since in many instances complicated structures require extensive machining for the proper fitup. Copper pickup into the weld is often encountered, and this requires grinding of the underside weld face, another costly operation.

Several types of granular backing material were evaluated with the following objectives:

1. Determine the optimum backing material that will give the desired physical properties, such as surface tension, fluidity and melting point.

2. Determine the optimum amount of backing material to give the desired bead contour on the underside of a root pass, and a simple method of holding this backing material in position.

3. Determine the limit of a root spacing, joint fitup and misalignment that can be tolerated to give the desired contours when the backing material is used.

4. Evaluate mechanical properties of the weld deposits to insure that these properties have not been affected by dilution with the backing materials.

In the initial work, several welding processes were used to evaluate the different backing materials, but soon after it was decided to concentrate on only one process. In this way, the welding conditions could be held constant instead of varying from process to process during the development of the optimum backing material. Welding was done with the manual electrode process where the limit of root spacing, pass fitup, and misalignment was taken into consideration by using the wide $\frac{1}{4}$-in. root spacing with a $\frac{3}{16}$-in. diam electrode. Experimental weldments were tacked together without special jigs, thus approximating field-welding conditions.

After the preliminary examina-

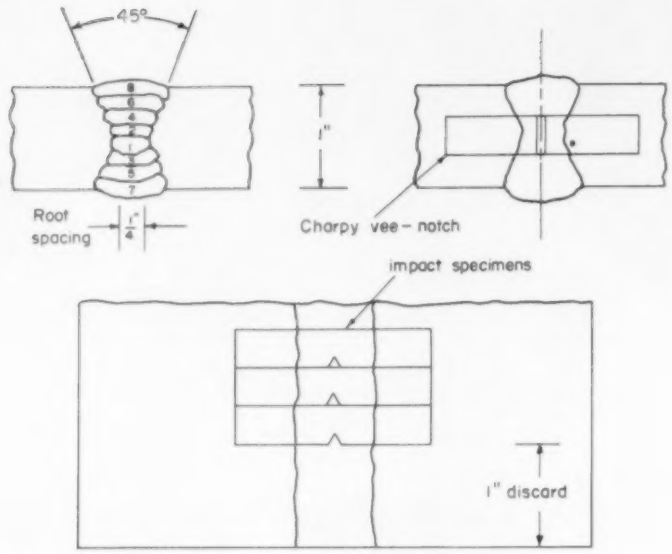

Fig. 1—Joint design, pass sequence, and impact specimens in a multipass weld

tions were completed, manganese-molybdenum armor plate, 1 in. thick, was used as the base material. A typical chemical composition of this base material was: C—0.26, Mn—1.73, Mo—0.46, Si—0.20, Ni—0.20, Cr—0.06, S—0.025 and P—0.019. The weld root spacing was set at 1/4 in. and the included double-vee bevel angle at 45 deg. This typifies the type of joint used.

Many different backup materials were evaluated during the course of this project. They ranged from nonmetallic granular materials to oxidized aluminum-coated spherical steel shot. The sizes, shapes and compositions of these materials were varied in order to determine effect on the underside weld contour. Each will be described in detail in its respective order under Experimental Results.

The method of holding the backup in the weld junction area was not changed throughout the progress of this work. Every backup material was supported in the weld groove by the use of a 2-in. wide strip of masking tape. The tape was applied to the underside of the weldment and then the backup material was poured into the junction area where it was adjusted so that it was level with the root of the double-vee groove.

A low-hydrogen MIL 230-16 ferritic electrode, 3/16 in. diam, was used to make the root pass in double-vee joints in 1-in. armor plate. The root gap width was 1/4 in. MIL 230-16 electrodes have the following typical chemical composition: C—0.08, Mn—0.75, Mo—0.29, Si—0.21, Ni—1.72, S—0.022, P—0.022 and V—0.12.

Welding Conditions

Manual welds were deposited downhand into the weld joints of all specimens.

The electrode was held approximately 5 to 10 deg from a line normal to the weldment and in a backhand position. No weaving motion of the electrode was allowed when depositing the first weld bead. Single bead welds were the predominant type made in order to evaluate the underside weld contour. Complete welds were deposited for overall evaluation after the contour shape was fixed. See Fig. 1 for the joint design and pass sequence.

The standard weld-layer sequence was used, except that no surface temper passes were deposited. Instead, only eight weld passes of MIL 230-16 weld metal were used to fill the entire joint area. It was decided that, since all tests were to be made near the center or root of the weld area, the absence of the temper passes would not alter the results of the hardness and impact tests. The optimum conditions for welding with the 3/16 in. diam MIL 230-16 electrodes were 220 amp at 23 v. A reverse-polarity direct current was used throughout the program. A weaving motion of the electrode during welding was permitted in all passes except Pass No. 1. The maximum interpass temperature was 250° F.

Evaluation Techniques

Visual inspection was used to evaluate the underside weld contour. If the contour was flat, or preferably slightly concave, then a microscopic examination of the weld-zone cross section was made. Any evidence of cracking, inhomogeneous weld structure, slag inclusions and nonfusion at the weld-metal base-material interface was recorded during this phase of the evaluation.

Hardness values were taken from the cross sections of single beads and complete welds which had the desired underside weld contour. Both Vickers (10-kg load) and Knoop (100-g load) indentations were made for the hardness evaluations. Vickers hardness was used mainly for average hardness values in the weld zone. Knoop hardness indentations (100-g load) were made vertically through the weld-metal zone, when there was considerable dilution of the weld material by the armor base material.

Chemical analyses for carbon content were made on numerous single-bead welds which had the desired underside contour. Samples were taken from the top and bottom of the weld. A difference in carbon content between the two sample locations indicated weld dilution by the backup material.

Charpy vee-notch impact bars were machined from armor-plate weldments after X-ray examination to insure that the welds were sound. The impact bars were positioned transverse across the root of the weld zone, and the notch was normal to the top of the weldment (Fig. 1). A standard Charpy impact machine was used to evaluate the ductility of the bars at 79, 0 and −40° F.

There was also a hydrogen and water-vapor analysis performed on the oxidized aluminum-coated steel backup shot at a temperature of 1000° F. This analysis was carried out mainly to check on the method of coating the steel shot particles.

Experimental Results and Discussion

In the interest of clarity in covering the many weld backing materials evaluated during the research program, materials of specific types have been grouped together. Each backing material is discussed separately in its appropriate group.

Welds Backed with Iron Powder

Two types of commercial iron powder were used initially as backing for the plate weldments. The first type was an electrolytically produced iron powder. The particles of this powder were small flakes. The second iron powder backing material was a granular powder

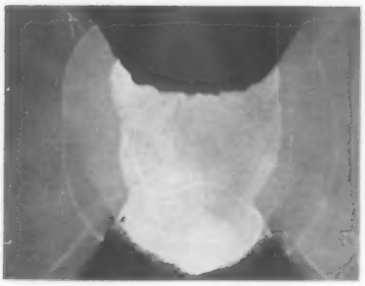

Fig. 2—Single weld pass backed by flake iron powder (−35 + 100 mesh). Picral etch. × 5. (Reduced approximately 50% on reproduction)

which was made by reducing mill scale with hydrogen. Both of these powders were essentially pure iron.

Flake Iron-Powder Backup. A typical composition given by the supplier for the electrolytically produced flake iron powder was: Fe—99.55, C—0.03, H_2 loss—0.35 and all others—0.07.

Rough and convex underside weld contours were characteristic in all cases when this material was used. Metallographic examination of cross sections of single-vee welds showed that the molten weld metal flowed into the iron powder (Fig. 2). Slag became entrapped between the weld and the base material, and it was difficult to melt out when depositing the cover-up pass on the underside of the weld. X-rays showed that when welding over the convex contours, porosity and slag entrapment usually resulted at the base-material weld-metal junction of the weld root. The amount of slag entrapment and porosity generally decreased as the root-gap width increased, but very few sound welds were produced.

The effect of backup particle size on the contours was evaluated using double-vee weldments with a $^1/_{16}$ in. root opening. Three different particle sizes were tried and, in general, there was little difference between the resulting underside weld contours.

Size group	Contour
(1) +35 mesh	Rough and convex
(2) −30 + 100 mesh	Rough and convex
(3) −100 mesh	Rough and convex

It was observed that when particle size Groups (1) and (3) were used there was slightly deeper penetration of the molten weld metal into the backup material. This was an indication that there was an optimum particle size of backup material in the −35+100 mesh range.

Granular Iron-Powder Backup. A typical composition of the granular iron powder used during this phase of the work was: Fe—97.5, C—0.17, Mn—0.30, Si—0.15, S—0.014, P—0.018, and H_2 loss—1.58. The shape of the backup particles was granular instead of the flake iron particles previously used.

Changing the shape of backup particle and altering the chemical composition slightly had very little effect on the underside weld contour. The contours on the underside of the weld were convex and almost identical with those contours resulting from the flake iron-powder backup. The size of the backup particles was varied from 30 mesh to 200 mesh with no definite changes in the resulting contour which would indicate an optimum backup particle size. The penetration of the weld metal into the backing material did, however, become more uniform as the size distribution of the backup particles was reduced. This indicated that size homogeneity was a factor that should be fixed in order to attain the desired smooth concave underside weld contours.

Table 1—List of Granular Backing Materials

No.	Material	Composition	Underside weld contour shape	Comments
1	FeMn	91.6% Mn, 0.5% C	Convex	Nonuniform contour
2	Fe + 2% Mn	.....	Convex	Uniform contour
3	FeSi	73.0% Si	Convex	Uniform contour
4	Fe + 2% Si	.....	Convex	Uniform contour
5	FeMnSi	47.8% Si, 21.7% Mn, 0.3% C	Convex	Nonuniform contour and deep weld penetration into backup
6	FeTi	41.9% Ti, 12.6% Si, 3.2% Al, 0.02% C	Convex	Uniform contour
7	Fe + 2% Ti	.....	Convex	Nonuniform contour and deep weld pentration into backup
8	FeCrSi	39.4% Cr	Convex	Nonuniform contour
9	SiMn	3.01% C, 67.4% Mn, 13.5% Si	Convex	Nonuniform contour
10	SiZr	35.04% Zr	Convex	Nonuniform contour
11	Fe + 0.1% S	.....	Convex	Uniform contour
12	Fe + 1.0% S	.....	Convex	Uniform contour and deep weld penetration into backup
13	Grade 80 flux	37.95% SiO_2, 25.30% CaO, 12.10% MgO, 10.55% Al_2O_3, 7.20% MnO	Flat to concave	Slightly nonuniform weld contour with a slag layer between weld and backup
14	Steel Sand No. 3	High SiO_2	Concave	Uniform contour with slag layer between weld and backup
15	Flux + Fe layer	.....	Flat to convex	Nonuniform contour with slag layer between weld and backup
16	Sand + Fe layer	.....	Concave	Slag layer between weld and backup—uniform contour
17	Sand + Fe mixture	50–50	Flat	Slag entrapment in weld metal

Welds Backed With Granular Materials of Several Different Compositions

All materials used as backing for weldments during this phase of work were granular in shape. A complete list of these materials is shown in Table 1. The iron material mentioned in Table 1 was −80+100 mesh granular iron powder which was used in initial evaluations. For example, Material No. 2 (Fe+2% Mn) was a mechanical mixture of FeMn and −80+100 mesh granular iron powder. Only two of the materials in Table 1, excluding layered backup combinations, yielded desirable underside weld contours. One material was Grade 80 flux, a neutral submerged-arc flux, and the other was foundry sand.

The Grade 80 flux particles were approximately −20+100 mesh in size. The underside weld contour produced with Grade 80 flux was flat in some areas, concave in others. Past work indicated that the weld contour could be made more uniform by using backup particles that were more homogeneous in size. The most important characteristic, however, was that a uniform continuous junction existed between the weld metal and base material. A wide angle (>90) separated the face of the beveled base plate and the underside weld surface. This made

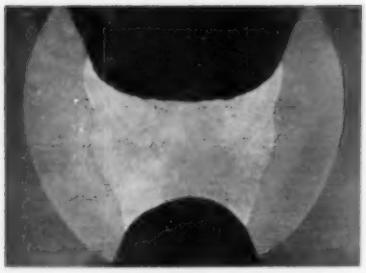

Fig. 3—Single weld pass backed by commercial cast steel shot A (−35 + 50 mesh). Picral etch. × 5. (Reduced approximately 50% on reproduction)

slag entrapment when depositing the cover-up weld pass improbable if good cleaning techniques were followed before welding. A thorough wire-brush cleaning was found to be adequate.

Welding over a steel sand backup resulted in uniform concave underside weld contours (Fig. 3). The particle sizes were somewhat finer than the flux backup and were in the range of −50+200 mesh size. A uniform continuous junction existed between the base material bevel face and the underside weld surface with even a wider angle (>135). The concave weld contour made slag entrapment very improbable when depositing a cover-up weld pass on the underside weld area.

There was one characteristic other than contour shape which was common to both backing materials. This was the presence of a thin slag layer between the backup material and weld metal after welding. In all the backup materials previously tried, no definite slag layer was found between weld metal and backup. Small particles of slag were sometimes observed embedded in the underside weld surface or near the fusion line of the weld metal and base metal, but the contour was always convex. Concave contours resulted only when a uniform slag layer was formed between the weld metal and backup. A backup material's ability to help form a concave underside weld contour appeared to be related to its slag-producing qualities.

Examination of the slag layer between the backup and weld metal revealed that it was glassy and highly viscous. Its properties appeared to be related directly to the high silica (SiO_2) content of the backup materials. Silica favors the formation of a highly viscous slag. This viscous slag seemed to hold the molten weld metal in the root-gap area instead of letting it penetrate deep into the backing material. The weld metal was fused with the base material adequately and formed the concave weld contour. It was recognized that part of the slag also came from the electrode coating during welding, but the viscosity was determined mainly by the constituents from the backup material. The greater weld concavity of the sand-backed weldment, compared with the shape of the flux-backed weldment, correlated with the higher silica content. The silica content of the flux was approximately 38% but the presence of some of the other higher melting temperature constituents such as CaO and MgO, probably caused the uneven melting of the backup. This mixture of constituents in the flux backup accounted for the nonuniform flat-to-concave underside weld contour produced in weldments.

Several combinations of flux, sand and −80+100 mesh granular iron powder were used for backup materials with little success. The best two-layer backup combination was the steel sand with a thin layer of iron powder on top. A concave weld contour resulted with a uniform slag layer present between the weld and backup. When using the flux in place of the sand, a nonuniform and rough weld contour resulted. A steel sand plus iron-powder mixture resulted in relatively flat weld contours with nonuniform slag layers between weld metal and backup. Slag entrapment occurred in the first weld pass. It was concluded that the addition of the granular iron powder offered nothing in the way of improvement in the weld contours. The remaining backing materials in Table 1 all resulted in convex underside weld contours.

With the experience gained through the use of sand and flux backups, work was then directed toward evaluating the remaining available ferrous materials as backing for armor-plate weldments.

Welds Backed With Spherical Shot Materials

Commercially available iron and steel shot was used initially as backing material for manganese-molybdenum armor-plate weldments. The chemical composition was then varied by making several special heats of steel shot. Table 2 lists the backup materials, their chemical compositions, and the type of weld contour produced.

Welds made with the chilled iron shot backup (−12+16 mesh) had very rough convex underside contours. No uniform slag layer between the backup and weld

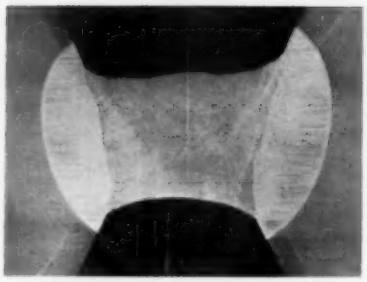

Fig. 4—Single weld pass backed by commercial cast steel shot A (−35 + 50 mesh). Picral etch. × 5. (Reduced approximately 50% on reproduction)

metal was observed and the weld contained serious center-line weld hot cracks. The hot cracking was found to be the result of carbon picked up from the backup material.

The carbon content of the backup was decreased by using the commercial cast steel shot A as the backing material. This is the type normally used in shot cleaning processes. The resulting weld contour was very smooth and concave (Fig. 4). A thin slag layer also was present between the backing material and weld metal. The manganese and silicon of the backing material appeared to be available at the weld root area in the right proportions to help form a thin layer of slag. This slag was sufficiently viscous to keep the weld metal from penetrating deeply into the backup and to allow the wetting action of the weld metal along the base material to take place.

Some centerline weld hot cracking was experienced when using the cast steel shot A. Microscopic examination showed a martensitic structure existing along with bainite or acicular ferrite phase in the weld metal. The martensite usually occurred in the center weld regions where the majority of weld cracking was observed. A carbon analysis revealed 0.32% carbon in the weld metal in contact with the backup and 0.25% carbon in the weld metal of the upper weld region furthest away from the backup. This was conclusive evidence of carbon pick-up by the weld from the backup material.

Cast steel shot B (0.65% carbon) was used also as a backing material, but the carbon content was still high enough to cause hot cracking. Also, the high sulfur and phosphorus contents were undesirable. The weld contour was rough and convex again and no definite slag layer was found between the backup and weld metal.

In order to eliminate the weld cracking that occurred when welding

over commercial steel shot, several special heats of shot were made with carbon, phosphorus, and sulfur contents (Table 2).

When using Battelle shot I as a backing material, crack-free welds were produced but the underside contour was convex. Setting the manganese and silicon contents to match those in the commercial steel shot A, yet keeping the carbon, phosphorus, and sulfur low was accomplished in Battelle shot II. This backup shot resulted in smoother convex weld contours with a definite slag layer existing between the backup and weld metal. However, a small amount of weld hot cracking was still observed. The reason for the convex weld contour obtained when using this type of backup material was not completely understood. Several possible explanations were that:

1. The presence of carbon, phosphorus and sulfur could have changed the viscosity of the slag layer.

2. The possible existence of some hollow shot particles which when hot did not have the strength to hold up the slag layer and molten weld metal.

3. The increased tendency for the melting of backup shot when all the particles are not completely spherical.

Two additional compositions of backup shot were evaluated which approximated the compositions of A-632 and A-675 welding wire (Table 2). The carbon content of these backup materials was much lower than all the other backup shot. The resulting underside weld contours were generally slightly convex, but in several weldments the contours were nearly flat. A slag layer was again formed between the backup material and weld metal. No weld cracking was encountered in welds backed with shot of Compositions A-632 and A-675. The underside weld contour was slightly better than the weld contour in weldments backed with the Battelle shot II. This was attributed to the more uniform shape of the backup particles.

The uniformity of the underside weld contour also depended upon the size range of backup particles used. Backup particles larger than 20 mesh usually yielded convex weld contours. The space between particles of this size was excessively large and this allowed the slag to flow down into the backup. The lower particle size limit was approximately 50 mesh, although good results were sometimes recorded with commercial steel shot A as small as 75 mesh. The determining characteristic here was the tendency for the welding arc to blow out the backup shot ahead of it as the welding proceeded.

Table 2—Spherical Shot Backing Materials

Name and particle size	C	Mn	Si	P	S	Comments
Chilled iron shot (−12 + 16 mesh)	2.95	0.45	1.40	0.070	0.085	Serious weld cracking with convex underside weld contours. No definite slag layer between backup and weld
Cast steel shot A (−35 + 50 mesh) and (75 mesh)	0.96	0.82	0.70	0.032	0.054	Concave weld contour with weld cracking. Slag layer present between backup and weld.
Cast steel shot B (−10 + 14 mesh)	0.65	0.50	1.50	0.100	0.100	Convex contour with weld cracking. No definite slag layer present.
Battelle shot I (−35 + 100 mesh)	0.18	0.46	0.26	0.001	0.003	Convex contour improved slightly by shape change—no cracking but some weld porosity, no definite slag layer.
Battelle shot II (−40 + 50 mesh)	0.25	0.80	0.70	0.007	0.014	Convex contour with definite slag layer.
A-632 shot (−40 + 50 mesh)	0.08 0.42 Mo	1.33 1.32 Ni	0.50 0.12 Cr	0.016	0.016	Convex to flat weld contours. No weld cracking. Small amount of slag between backup and weld.
A-675 shot (−30 + 40 mesh)	0.10	0.95	0.45	0.025	0.025	No weld cracking. Convex to flat weld contour. Small amount of slag between backup and weld.

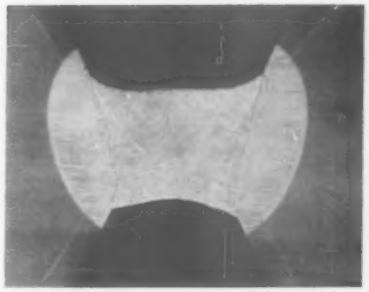

Fig. 5—Single weld pass backed by oxidized aluminum-coated electrode shot (−30 + 40 mesh). Picral etch. × 5. (Reduced approximately 50% on reproduction)

An interesting effect of backup particle shape was observed when using a steel grit backup. Steel grit of approximately 50 mesh size, with the same composition as the commercial cast steel shot A, yielded convex underside weld contours, whereas the spherical cast steel shot A yielded concave weld contours. An irregular slag layer was formed but the effect of shape homogeneity was clearly observed. It appeared from the observations made that spherical particles were advantageous because under such conditions less heat was carried away by the backup. Thus, the molten metal flowed along the bevel faces more readily.

It seemed likely that the quality of the weld contour could now be improved by changing the viscosity of the slag layer formed between the weld metal and backing materials. This premise was evaluated through the use of chemical coatings on the shot surface.

Welds Backed with Specially Coated Steel Shot

Using a backing material such as Battelle shot II that was known to produce a slag layer between weld metal and backup, a (Na_2SiO_3) sodium silicate surface coating was applied to the particles to increase the viscosity of the slag layer. The Na_2SiO_3-coated shot was dried for 10 hr at 95° F in a constant humidity and temperature-controlled electrode storage room. Armor baseplate specimens welded when backed with this coated shot yielded uniform flat-to-concave underside weld contours. There was a relatively thick slag layer formed between the backup and weld metal compared with the slag layer formed when using the uncoated Battelle steel shot II. This slag layer was very

difficult to remove for subsequent weld passes. For this reason, the search continued for another shot coating material to increase the viscosity of the slag layers without increasing the amount of slag.

When welding specimens backed by steel shot coated with oxidized aluminum (Al_2O_3), flat-to-concave weld contours resulted. Only a thin slag layer was produced in these welds because of the high melting temperature of Al_2O_3, but the slag viscosity was apparently increased. In addition to the slag layer viscosity appearing responsible for the underside weld contour, literature sources*,† indicated the possible effect of the molten metal surface tension. A thin molten layer of shot with a relatively high surface tension could favor the wetting of the bevel faces by the molten weld metal because of the condition of lower surface tension existing in that area. The over-all effect was probably a combination of slag viscosity and molten metal surface tension.

To produce an oxidized aluminum coating on the shot, a high-temperature aluminum paint of the following composition was used:

Aluminum paste	22.5%
Petroleum resin	19.3%
Coal tar solvent	8.6%
Petroleum spirits	49.6%

A few drops of this paint were put into a small container of steel shot. The container was then closed and agitated to completely cover all the shot particles. The amount of aluminum required to coat the shot was less than 4 lb per ton of shot or less than 0.2 weight per cent of the shot. After the coating process, the shot was baked at 325° F for 1 hr. Most of the resin, solvent and petroleum spirits were driven from the aluminum paint during this baking period, leaving essentially a thin layer of aluminum which is known to oxidize almost immediately.

Welds made with shot coated with the oxidized aluminum gave underside weld contours which were uniform and flat to slightly concave. The slag layer was approximately $^1/_{16}$ in. maximum thickness and easily removed. A sufficiently wide included angle between the base-material bevel face and the underside weld surface made cleaning and the deposition of the underside cover-up weld pass a simple procedure. Similar results were found when welding specimens backed with oxidized aluminum-coated A-632 and A-675 steel shot.

Welds Backed With Oxidized Aluminum-Coated Shot Approximating the Composition of the Manganese-Molybdenum Armor Plate and the MIL 230-16 Welding Electrode

Desirable concave underside weld contours were produced when using most oxidized aluminum-coated backing materials. Sound welds, however, were not always obtained. This was attributed to weld dilution by elements contained in the backing material. For example, weld hot cracking often occurred because of the relatively high carbon, phosphorus, and sulfur contents in the backing materials. To insure that no detrimental elements were introduced into the weld metal, two special steel shot backing materials were made. One approximated the composition of the manganese-molybdenum armor plate and the second approximated the composition of the welding electrode MIL 230-16. The following are typical compositions of these backing materials:

	Armor shot	Electrode shot
C	0.27	0.08
Mn	1.80	1.00
Si	0.70	0.32
Ni	0.54	1.75
Mo	0.53	0.30
V	...	0.10
S	0.022	0.022
P	0.007	0.003

Weldments backed with the oxidized aluminum-coated armor shot and also the electrode shot yielded flat-to-concave underside weld contours which were very uniform (Fig. 5). No hot cracking was observed in welds backed with either type of shot.

Evaluation of Welds Made With Oxidized Aluminum-Coated Backing Materials

A carbon analysis was made on single bead welds backed with the oxidized aluminum-coated steel shot particles. Vickers hardness values (10-kg load) of the weld zone were compared then with the carbon analysis and the tendency for center-line weld cracking. Table 3 summarizes the results.

The higher carbon steel shot backup produced more weld cracking than the lower carbon steel shot. The maximum limit of carbon content in the shot appeared to be about 0.25%. Although the armor shot contained 0.27% carbon, no weld cracking was observed. This was attributed to a smaller amount of carbon pickup by the weld and also to the relatively higher manganese content of the armor shot compared with the Battelle shot II. The Vickers hardness values supported the chemical analysis data by showing higher hardnesses for welds with a higher carbon content.

Metallographically, the weld cross sections of weldments backed by the oxidized aluminum-coated armor, electrode, and A-675 shot all revealed structures of acicular ferrite or bainite. The area surrounding the weld cracks in specimens backed by the oxidized aluminum-coated Battelle shot II, however, was martensite. In the welds backed by the cast steel shot up to 40% of the structure was martensite with the majority occurring in the center weld area where the cracking was observed.

Charpy vee-notch impact bars were machined from the root weld area of completely filled weld junctions (see Fig. 1). A copper-backed weld was used as a standard for

Table 3—Relation of Per Cent Carbon in Single Bead Welds to Average Weld-Zone Hardness

Backing material	Average weld-zone hardness (10-kg Vickers)	Carbon in weld metal nearest backup, %	Center-line weld cracking
Cast steel shot A (0.95% C) (−25 + 40 mesh)	320	0.32	Very frequently occurred
Oxidized aluminum-coated Battelle shot II (0.25% C) (−20 + 35 mesh)	272	0.16	Sometimes occurred
Oxidized aluminum-coated armor shot (0.27% C) (−30 + 40 mesh)	263	0.14	None observed
Oxidized aluminum-coated electrode shot (0.08%C) (−30 + 40 mesh)	250	0.11	None observed
Oxidized aluminum-coated A-675 shot (0.10% C) (−20 + 40 mesh)	247	0.10	None observed

* Hazlett, T. H., "Coating Ingredients' Influence on Surface Tension, Arc Stability and Bead Shape," THE WELDING JOURNAL, 36 (1), Research Suppl., 18-s (1957).

† Weare, N. E., Martin, G. E., and Monroe, R. E., "Studies of Welded Ferrous Overlay Rotating Bands," Summary Report to Frankford Arsenal, Contract No. DA-33-019-507-ORD-3, Battelle Memorial Institute, September 13, 1957.

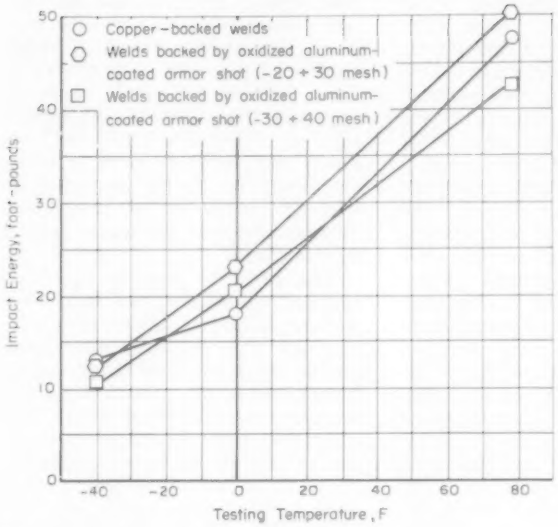
Copper-backed welds
Welds backed by oxidized aluminum-coated armor shot (-20 + 30 mesh)
Welds backed by oxidized aluminum-coated armor shot (-30 + 40 mesh)
Impact Energy, foot-pounds
Testing Temperature, F

Fig. 6—Comparison of Charpy vee-notch impact values between copper-backed welds and welds backed by oxidized aluminum-coated armor shot

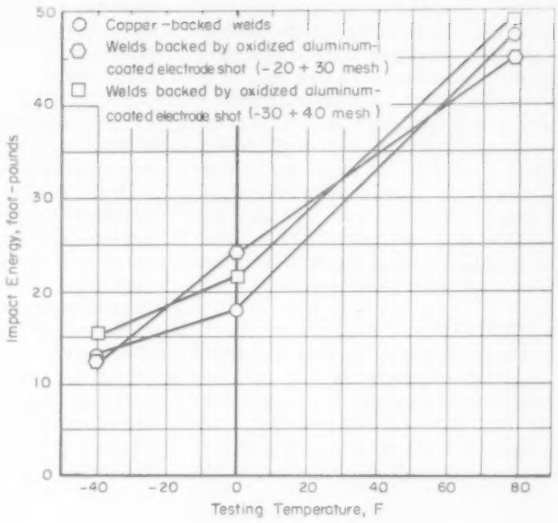
Copper-backed welds
Welds backed by oxidized aluminum-coated electrode shot (-20 + 30 mesh)
Welds backed by oxidized aluminum-coated electrode shot (-30 + 40 mesh)
Impact Energy, foot-pounds
Testing Temperature, F

Fig. 7—Comparison of Charpy vee-notch impact values between copper-backed welds and welds backed by oxidized aluminum-coated electrode shot

comparing the ductility values. Curves summarizing the results of the impact tests are shown in Fig. 6 and 7. The ductility curves for the welds backed by the oxidized aluminum-coated armor and electrode shot compared favorably with those for the copper-backed weld.

Although the welds backed by the oxidized aluminum-coated shot were in general more ductile than the copper-backed welds, the impact values were grouped tightly together. Tight grouping of the impact values was attributed to weld dilution by the armor base plate during the first few weld passes. The oxidized aluminum coating on the backup shot showed no ill effect upon the impact properties of these welds.

The presence of weld dilution with the armor plate was detected by the use of Knoop hardness tests (100-g load) taken vertically through the weld-metal zones of specimens backed by oxidized aluminum-coated electrode and armor shot. The evaluation revealed an increase in hardness near the center or root of the welds (Fig. 8). This was the result of carbon pickup from the armor base plate at the weld root area.

An attempt was made to reduce weld dilution by incorporating a $^1/_8$ in. land in the weld junction and by decreasing the welding amperage from 220 to 190 amp. Impact specimens were machined from completed welds, backed by $-30+40$ mesh oxidized aluminum-coated electrode shot and tested. The results gave a ductility curve very similar to those obtained when aluminum-coated shot having the compositions of armor or electrodes were used (Figs. 6 and 7).

Reduction of the power input and alteration of the joint configuration did not reduce the weld dilution. The impact values obtained, however, still compared favorably with those obtained for welds backed by copper bars.

The effect of water and hydrogen contents of the oxidized aluminum-coated backup shot upon the impact ductility was considered to be very small. The maximum moisture content of 0.24% appearing in Specification MIL-E-986, "Electrode Welding Mineral Covered Low-Hydrogen As-Welded Applications on High-Strength Steels," Paragraph 4.6.9, was considered the maximum amount allowed in the backup material. A hydrogen and water-vapor extraction of oxidized aluminum-costed electrode shot ($-30+40$ mesh) at 1000° F revealed the following:

Shot baking treatment	Per cent H_2 from H_2O	H_2	Per cent total H_2
A 325° F for 1 hr	0.0054	0.0018	0.0072
B 500° F for 3 hr	0.0034	0.0020	0.0054

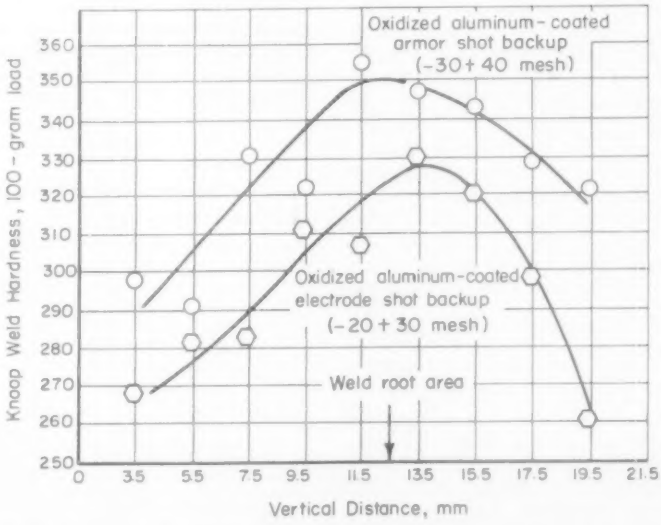
Oxidized aluminum-coated armor shot backup (-30+40 mesh)
Oxidized aluminum-coated electrode shot backup (-20+30 mesh)
Weld root area
Knoop Weld Hardness, 100-gram load
Vertical Distance, mm

Fig. 8—Hardness effects resulting from weld dilution with armor base plate

Baking Treatment A was the one used when preparing all the coated electrode shot used during this program. Treatment B was made to learn the effect of higher temperature-longer baking time. The total hydrogen content was well below that available in the maximum allowable moisture content of 0.24%. Longer baking time at an increased temperature decreased the total hydrogen content even more but was considered unnecessary.

Conclusion

Many different backing materials —nonferrous, ferrous and nonmetallic—were studied in an effort to develop granular weld backup materials and techniques. In every case where a suitable concave underside weld contour resulted, a definite slag layer was found between the backup and weld metal. The origin of the slag layer was both the backing material and slag-producing electrode covering. The viscosity of the slag layer, in some cases, was determined by the backing material. A viscous slag layer under the molten weld metal appeared to hold up the metal in the center of the root gap and allowed it to flow down and wet the sides of the base plate. Steel sand backups which contained high silica helped produce welds with a concave underside weld contour. The slag layer between the weld and backing material was very thick and difficult to remove. Commercial steel shot materials used as backups yielded welds with flat-to-concave underside weld contours. The slag layer was not so thick in this case. The viscosity effect here was thought to be associated with the composition of the steel shot.

Welds backed with the commercial steel shot (0.95% carbon) contained hot cracks through the center portion of the weld zone. The carbon, sulfur and phosphorus contents were too high, and particles of backup melting into the weld metal lowered the hot ductility enough to cause the cracks. Steel shot backup particles with lower carbon analysis (0.18% carbon), on the contrary, yielded convex weld contours with no cracking observed in the weld.

The viscosity of the slag layer was apparently increased through the application of Na_2SiO_3 (sodium silicate) surface coatings on the shot particles. Sodium silicate (water glass) coatings applied on the shot surface and then dried resulted in the desired concave weld contours being produced. The sodium silicate coating, however, was considered unsatisfactory. The slag layer became too thick and very difficult to remove, due to the relatively large amount of the water glass in the slag. An oxidized aluminum coating, which melted at a higher temperature, proved to be ideal when it was used as the surface coating on the shot. The slag layer was uniform and thin, easily removed from the weld, and the weld contour was concave.

Two possible effects of the oxidized aluminum coating were to increase the slag viscosity and to increase the surface tension of the initial thin layer of molten backup. Both of these actions could help produce the desired weld contours and it was assumed to be a combination of the two.

Weld cracking was eliminated by using a low-carbon steel shot with the oxidized aluminum coating. A final optimum composition of the shot approximated that of the MIL 230-16 electrode.

Charpy vee-notch impact properties of specimens taken from the root area of welds backed with the oxidized aluminum-coated shot compared favorably with those taken from standard copper-backed welds. In most cases, the impact strength of welds backed by the coated shot was slightly greater than for corresponding welds backed with copper. The impact values of welds backed by the −30 + 40 mesh oxidized aluminum-coated electrode shot were the highest of all the coated shot. Weld dilution by the base metal was found to exist in every specimen, but it did not interfere with the results because it occurred in approximately the same amount in every weld.

The effect of possible hydrogen pickup from the shot coating process was negligible. A hydrogen extraction of the oxidized aluminum-coated electrode shot after it had been baked at 325° F for 1 hr showed a total of 0.0072% hydrogen. This value was much less than the maximum allowable hydrogen content.

Research carried out thus far has shown that steel shot property chosen and prepared can be used to produce the desired underside weld contour in manually welded armor plate. The advantages of using this method are promising. The oxidized aluminum-coated steel shot backup eliminates the need for back chipping and the fixturing and preparation associated with copper backup bars. Therefore, economically, it is less expensive and much faster. It seems very probable that the shot backing method could soon replace many of the copper backing bars in production.

Acknowledgment

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Inserted Shim Projection Welding of a Continuous Rod Mat

Flat inserted shims serve as a suitable projection for resistance welding of thin parallel steel and nickel rods

BY KEH-CHANG WU AND RICHARD E. LEWIS

ABSTRACT. A research program was conducted to investigate the application of resistance welding to fabrication of a continuous rod mat. Due to the geometry of the welding joint, projection resistance welding was considered most promising.

Several types of inserted projections were investigated. An inserted flat shim proved to be most satisfactory. The purpose of using 422 modified stainless steel shim material was to obtain high joint strength without using high strength rod material which did not have the required bend ductility.

The 422 modified stainless steel shim was used in both the FS 1018 steel and A-nickel rod joints. It was found that the weld joint having a $^1/_2$-in. long shim was as strong as one having a $^3/_4$-in. long shim. The optimum welding conditions were determined for rods of FS 1018, both $^3/_{16}$ in. sq and 0.164- x $^3/_{16}$-in., and for 0.164-in. sq A-nickel.

Introduction

The welding of continuous rod mats has been conducted for the past several years. Higher joint strength has been a continuing goal to obtain greater effectiveness and reliability in its end use. A desired joint strength was arbitrarily set at 1200 lb for a two bar assembly of $^3/_{16}$-in. sq FS 1018 steel subjected to a special pull test. The request was made to conduct a study of electrical resistance welding of the continuous rod mat assembly.

Materials

The rod materials used for this investigation were FS 1018 steel and A-nickel. The cross-sectional sizes of FS 1018 steel rods were $^3/_{16}$-in. sq and 0.164- x $^3/_{16}$-in. rectangular. For A-nickel, 0.164-in. sq rod was used.

The inserted shim material used was 0.018-in. thick type 422 modified stainless steel.

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The chemical analyses of A-nickel and 422 modified stainless steel are listed in Tables 1 and 2 respectively. The chemical analysis of the FS 1018 steel rod is not listed as it fell within Federal standards.

Equipment

Welding

A 75-kva, single-phase a-c spot and projection welding machine was used for determining the optimum welding condition and making continuous rod mat sections of FS 1018 steel and A-nickel rods. A pair of Class 2 electrodes with flat surfaces were used in this investigation. A $^1/_4$-in. radius contour was produced on the leading edge of the electrodes to eliminate the sharp indentation formed on the rod during welding. The electrodes were $^5/_8$ in. wide and their length was so adjusted that the axis of the electrode holder bisected the inserted shim plus an appropriate bearing length as shown to the left in Fig. 1.

Table 1—Chemical Analysis of A-nickel

Element	%
Mg	0.02
Si	0.09
Fe	0.09
Cu	0.04
Mn	0.03
C	?
Ni	Balance

Table 2—Chemical Analysis of Type 422 Modified Stainless Steel

Element	%
C	0.22
Mn	0.54
P	0.026
S	0.015
Si	0.35
Ni	0.64
Cr	12.46
Mo	0.99
V	0.29
N_2	0.036
Fe	Balance

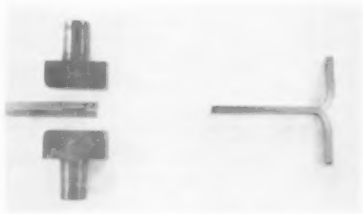

Fig. 1—Rods and shim in welding position (left) and test specimen (right)

The welding current was measured with a Duffer's Associates Secondary Current Meter with an accuracy of ± 3%.

Testing

Contact surface resistance was measured with a suitable surface resistance analyzer at an electrode force of 500 lb. The range of the resistance measurement is from 5 to 10,000 microhms.

The test specimens were made into a special shape as shown to the right in Fig. 1. An electronically controlled, variable speed, motor driven tension test machine was used for the specimen testing. The moving head of the test machine was operated at approximately 2 ipm at the beginning of the test. The speed was gradually slowed down to 0.2 ipm before the load reached 450 lb. From then on, the speed of the moving head was kept unchanged until the specimen failed.

The photomicrographs were taken with a suitable metallograph and the hardness measurements were made on an appropriate hardness tester.

Investigation Procedures

Surface Treatment

The heat used in electrical resistance welding is generated by current and the resistance in the contact surfaces. Contact resistance varies with the degree of cleanliness, roughness and oxidation of the metal surfaces. High contact resistance results in wide variation

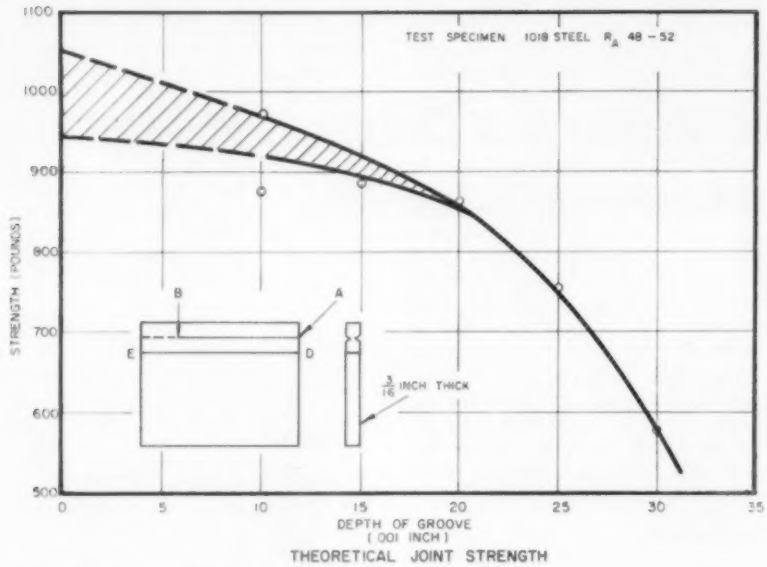

Fig. 2—Theoretical joint strength for $^3/_{16}$ in. square FS 1018 steel. Head travel speed of 0.005 in. per sec. (Not shown in sketch, "C" is section between top edge and line BA)

of resistance from weld to weld, which naturally changes the resultant weld properties. In order to obtain a consistent weld, a low-contact resistance is desired. Low-contact resistance is obtained by mechanical and chemical treatment of metal surfaces to be welded.

For FS 1018 steel rods, the surface treatment procedures were: degrease in acetone, pickle in 50% hydrochloric acid for 30 sec to 1 min, rinse in running water and wipe dry with clean towel. For quick drying, the specimen may be dipped into acetone after rinsing and dried in air. It is recommended that the storage period of pickled rod not exceed 48 hr in a shop environment.

The 422 modified stainless shim stock was degreased with acetone, pickled in 10% sulfuric acid at 150 to 160° F for 15 min, then rinsed in running water and wiped dry. Contact resistance did not increase appreciably within one week stored in shop environment.

A-nickel rod in as-received condition had a contact resistance of 150 to 300 microhms. After degreasing with acetone, the contact resistance decreased to 50 to 80 microhms. Wire brushing reduced this to 15 to 25 microhms. In practicality, it is suggested that A-nickel rod may be welded in just the degreased condition.

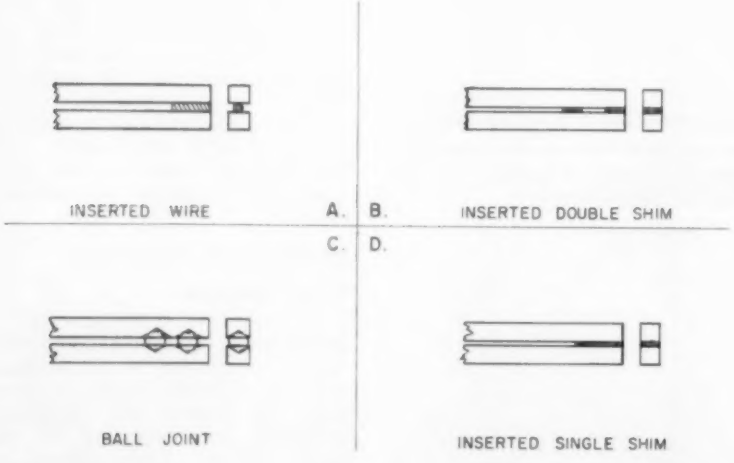

Fig. 3—Joint designs

Theoretical Strength of Welded Joint

To determine the theoretical strength of FS 1018 steel rods, a procedure was developed to obtain a quantitative value of maximum joint strength. Annealed FS 1018 steel specimens were prepared as shown in Fig. 2. Vee-shaped grooves of different depths were cut on the specimen from A to C in Fig. 2 on each side of the specimen. These specimens were sheared from A to B. The length of BC was approximately $^3/_4$ in. Each specimen was completed by sawing off along DE from a $^3/_{16}$-in. thick plate. Each leg was bent from its original plane 90 deg as shown to the right in Fig. 1.

The purpose of cutting a vee-shaped groove is to control the line of specimen failure along a longitudinal direction of a theoretical weld. The depths of grooving were 0.010, 0.015, 0.020, 0.025 and 0.030 in. The results obtained in this test are shown in Fig. 2. The curve plotted as the strength vs. depths of groove was extrapolated to zero depth of groove. This is the estimated strength of a test specimen without any groove. The latter is practically unobtainable as failure most often occurs in the rod perpendicular to the direction of pulling. The extrapolated strength of a 100% joint width specimen ranges from 950 to 1050 lb. Ignoring experimental error, it is indicated that $^3/_{16}$-in. sq FS 1018 steel bars will not reach the requirement of 1200 lb in the special pull test.

Type of Projections used in Weld

During the first phase of this investigation, different types of projections were studied.

A $^3/_{32}$-in. diam steel wire was first used as a projection. It was attempted to position a piece of $^3/_8$ in. long wire between the two rods at one end of the rod as shown in Fig. 3. Because of the difficulty of positioning the wire and the narrow fusion zone, the wire projection was not acceptable.

The possibility of using two-piece flat shim inserted projections was studied. This arrangement is also shown in Fig. 3. The difficulty of placing the two shims in the joint caused the abandonment of this technique.

A steel ball projection was then studied. As likewise shown in Fig. 3, two holes were drilled in the joint area on both rods. Two $^1/_8$-in. diam steel balls were placed into the cavities and used as joining material between the two rods. Unfortunately, steel balls commonly

available are made of high carbon steel, so the joint was very brittle even when the highest tempering cycle was used.

Finally, a flat shim projection, which was $^3/_4$ in. long, $^3/_{16}$ in. wide and 0.018 in. thick, was selected and used for the welding of FS 1018 steel rods. This joint is shown in Fig. 3.

Procedure to Optimize Welding Conditions

An electrode force was selected and the welding time and welding current were then varied. The welding time is dependent upon the thermal conductivity of the material. In order to obtain the most efficient heating effect, the welding time should be kept as short as possible. However, this increases the tendency toward expulsion of metal from the weld. A welding time longer than required leads to excessive deformation. On the other hand, the minimum welding time is limited by the time required to obtain a complete metallurgical bond.

After the minimum welding time was determined for the selected electrode force, another electrode force was selected. In order to keep the deformation to a minimum, electrode force is made as low as possible without expulsion.

The optimum welding condition is considered to be the one under which the highest, reproducible, joint strength is obtained without excessive deformation. A con-

Table 3—Optimum Welding Conditions for FS 1018 Steel and A-nickel Rods Using an Inserted Shim Projection[a]

Material	FS 1018 steel rod			A-nickel rod
Rod size, in.	$^3/_{16}$ in. sq	$^3/_{16}$ in. sq	$^3/_{16} \times 0.164$[b]	0.164 sq
Shim length, in.	$^1/_2$	$^3/_4$	$^7/_8$	$^1/_2$
Electrode force, lb	680	1000	1120	880
Weld current, amp	7500–8100	9500–10,500	10,000–11,000	14,400–15,200
Weld time, cycles[c]	120	120	120	60
Chill time, cycles	360	360	360	...
Temper current, amp.	6600–7000	8500–9000	7500–8600	...
Temper time, cycles	120	120	120	...
Hold time, cycles	30	30	30	30
Avg. joint strength, lb	996	941	845	904
Std. deviation, lb	49	76	62	47
Strength range, lb	225	265	195	180
Electrode bearing length, in.	$^3/_4$	1	$1^1/_2$	$^3/_4$

[a] Shim is Type 422 modified stainless steel, 0.018 in. thick x $^3/_{16}$ in. wide.
[b] Welded on 0.164 in. side.
[c] Each cycle is $^1/_{60}$ of a second.

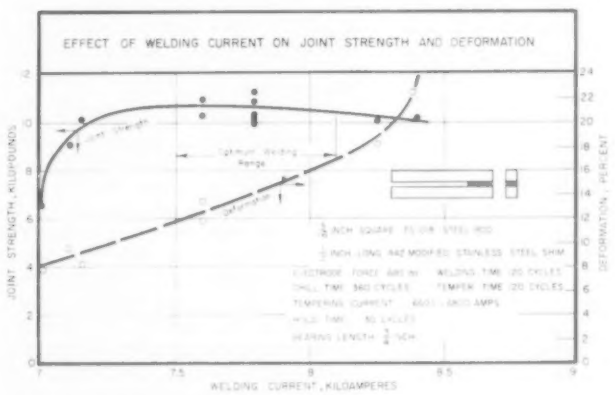

Fig. 4—Effect of welding current on joint strength and deformation for optimum welding conditions of FS 1018 steel rod

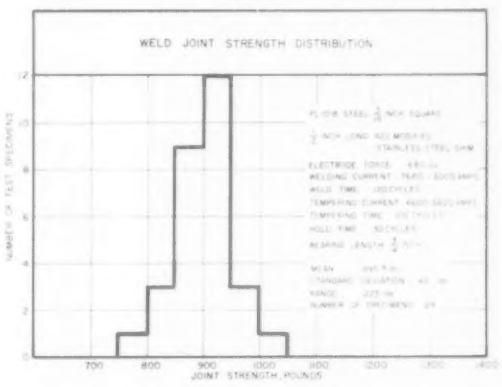

Fig. 5—Weld joint strength distribution of FS 1018 steel rod

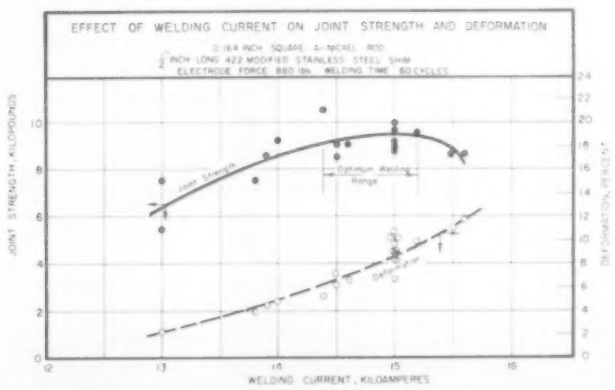

Fig. 6—Effects of welding current on joint strength and deformation for optimum welding conditions of A-nickel

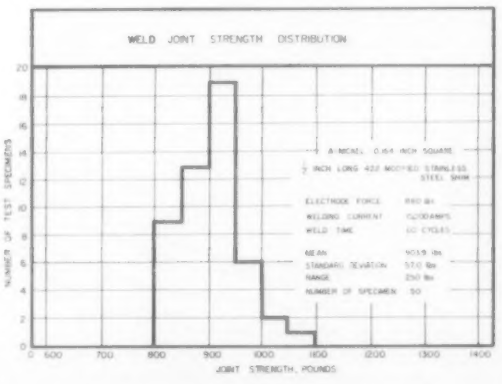

Fig. 7—Weld joint strength distribution of A-nickel

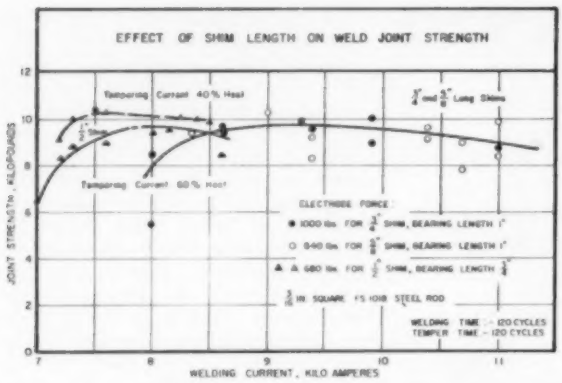
EFFECT OF SHIM LENGTH ON WELD JOINT STRENGTH
Tempering Current 40% Heat
Tempering Current 60% Heat
ELECTRODE FORCE:
1000 lbs. FOR 3/4" SHIM, BEARING LENGTH 1"
840 lbs. FOR 5/8" SHIM, BEARING LENGTH 1"
680 lbs. FOR 1/2" SHIM, BEARING LENGTH 3/4"
3/16 IN. SQUARE FS 1018 STEEL ROD
WELDING TIME - 120 CYCLES
TEMPER TIME - 120 CYCLES
JOINT STRENGTH, KILOPOUNDS
WELDING CURRENT, KILO AMPERES

Fig. 8—Effect of shim length on weld joint strength

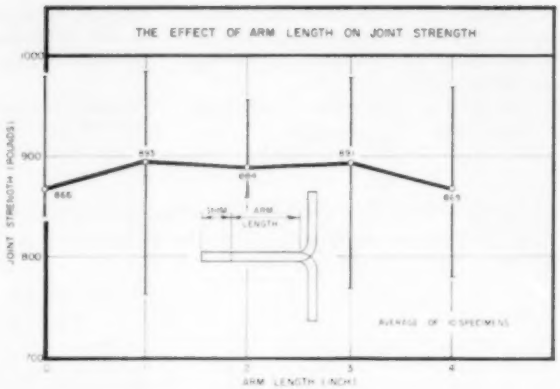

Fig. 9—Effect of arm length on weld joint strength

trolled small amount of deformation is necessary to produce a strong metallurgical bond. The degree of metallurgical bonding is increased by more heat at the contact surfaces which in turn produces more deformation (for constant electrode force and welding time). In this case, the limit of deformation is set at 15% of the original thickness.

The length of the shim within the tested range did not affect the joint strength appreciably. For practical reasons, a $^1/_2$-in. long shim was chosen for production of the continuous rod mat.

Results

Optimum welding conditions were determined for three specific cases, after investigation over a wide range of the variables of electrode force, welding current, welding time, tempering current and tempering time. Table 3 presents these optimum conditions. More details on the effects of the variables are shown in Figs. 4 through 11.

The effect of welding current on joint strength and deformation for FS 1018 steel ($^3/_{16}$-in. sq rod) is shown in Fig. 4. The weld joint strength distribution of 27 specimens is shown in Fig. 5. The effect of welding current on joint strength and deformation for A-nickel (0.164-in. sq rod) is shown in Fig. 6, with the weld joint strength distribution of 50 specimens shown in Fig. 7.

The effect of the length of the inserted shim (in turn, the length of the joint) on joint strength was investigated. The results disclosed no difference in joint strength when the length of the shim was reduced from $^3/_4$ to $^1/_2$ in. The results are shown in Fig. 8.

Researchers working on the welding of the continuous rod mat have disagreed about the effect of arm length on the joint strength of the test specimens. To clarify this, test specimens were made with arm lengths of 0, 1, 2, 3, and 4 in. long, respectively, measured from the inner end of the shim when the bend started as shown in Fig. 9. There were 10 specimens made for each arm length. The results of this test are likewise shown in Fig. 9. During the test, the angle between the arms of the test specimen was recorded at successive times by photographs and the corresponding load was recorded at the same time. The angle between the arms during loading for various arm lengths is shown in Fig. 10. Data from three specimens comprise each curve.

The hardnesses measured across the weld zone in as welded and tempered steel rod and as welded "A" nickel rod are shown in Fig. 11.

Discussion

Because of test methods and manners of application, the material of the rod has to be ductile enough to withstand a 90 deg bend with a radius less than its thickness. In steel, only the ones which contain low carbon qualify for this work. High strength steel rods such as FS 4140 and T-1 fail before reaching 90 deg sharp radius bend angle. However, low carbon steel does not have high enough strength. An inserted alloy shim with mild steel rods, however, serves to:

1. Increase the joint strength by alloying, but still retain

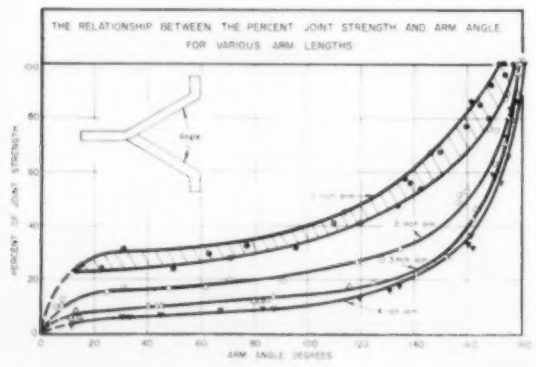
THE RELATIONSHIP BETWEEN THE PERCENT JOINT STRENGTH AND ARM ANGLE FOR VARIOUS ARM LENGTHS
PERCENT OF JOINT STRENGTH
ARM ANGLE DEGREES

Fig. 10—Relationship between the percent joint strength and arm angle

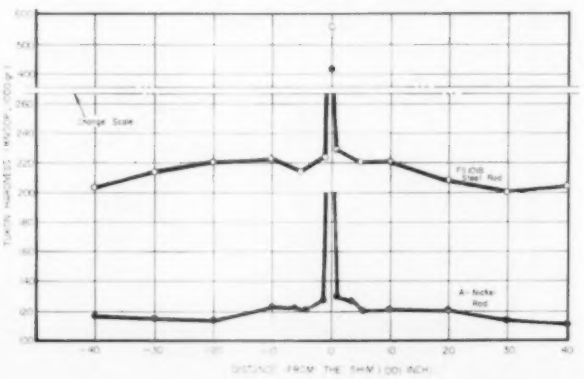

Fig. 11—Hardness measurements in the weld zone

ductility in the base metal.
2. Improve the welding current distribution at the faying surfaces.
3. Control the length of joint.

The inserted shim controls the flow of welding current into a definite area. The length of the shim should be less than the shaft diameter of the electrode, otherwise the uniformity of welding current distribution is difficult to control.

Figure 8 shows the joint strength of a $^1/_2$-in. long shim is slightly higher than that of a $^5/_8$-in. or a $^3/_4$-in. long shim. Standard deviation of strength was lower for a $^1/_2$-in. long shim than that for a $^5/_8$- or $^3/_4$-in. long shim. This may be attributed to higher uniformity

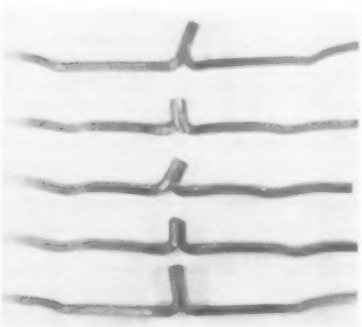

Fig. 12—Twisting of specimens during test

of welding current in the $^1/_2$-in. long shim. It has also been observed that the shorter the welded joint, the less variation in twisting of the joint during test. Different degrees of twisting during test are shown in Fig. 12. This may very well affect the consistency in the weld joint strength.

An inserted shim projection may be used for strengthening the joint, which is dissimilar to the base metal. Here the suitable shim material should be selected not only on its mutual solubility with the base material but also because of its difference in melting point from the base material. Because the temperature in the faying surface during welding is always higher than the melting point of the base metal, a shim would melt even if its melting point were higher than that of the base metal. However, it is inadvisable to choose a shim material that has a melting point more than 150° F above the base metal since the higher the overshoot temperature, the higher the tendency of expulsion at any specific electrode force. For example, a strong weld joint of Cupro-Nickel

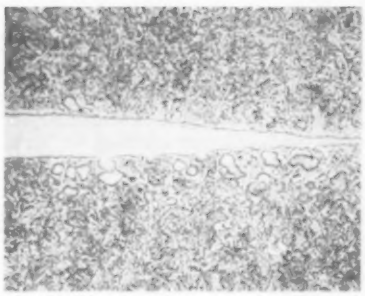

Fig. 13—Microstructure of weld zone of FS 1018 steel with 422 modified stainless steel shim. (Reduced 50% on reproduction)

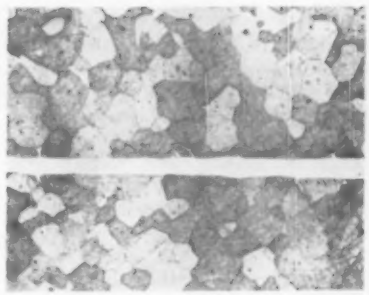

Fig. 14—Microstructure of weld zone of A-nickel with 422 modified stainless steel shim. (Reduced 50% on reproduction)

(55% Cu, 45% Ni) with 422 stainless steel shim could not be obtained because there is a wide difference in melting point between the shim and the base metal (2700 to 2740° F vs. 2300° F).

In this case, the base metal was melted long before reaching the melting point of the shim material. As soon as the base metal was melted and some expulsion took place, the continuity of the path of welding current was disrupted. Due to the geometry of the weld joint, an increase of electrode force cannot eliminate expulsion. Instead, it only increases joint deformation.

Nickel has higher thermal conductivity than that of steel (575 vs. 360 Btu/sq ft/hr/° F/in.). Therefore, the optimum welding time is shorter for A-nickel than for FS 1018 steel (60 cycle vs. 120 cycle). In order to avoid expulsion, a higher electrode force was used for nickel rod than that for FS 1018 steel rod (880 lb for 0.164-in. sq nickel rod vs. 680 lb for $^3/_{16}$-in. sq FS 1018 steel rod, $^1/_2$-in. long shim used in both cases).

A tempering cycle was used in FS 1018 steel for preserving its ductility but was not used in the A-nickel rod welding procedure. This was because A-nickel does not have any allotropic transformation, and the martensitic stainless steel shim is so thin (about 0.001 to 0.003 in. thick) after welding that the brittle nature of this shim layer is compensated for by the surrounding ductile nickel. Instead, the joint is strengthened. The microstructures of the welded steel and the A-nickel rod are shown in Figs. 13 and 14 respectively. Metallurgical bonding can be seen in the region adjacent to the stainless steel shim.

The alloying effect of the stainless steel shim is further confirmed by the hardness measurement in the weld zone shown in Fig. 11. The hardness reading is increasing as the measurements approach the shim. The width of the alloyed zone is about 0.010 in. on either side of the shim.

An experiment of the effect of arm length on the joint strength was performed. The results showed that the arm length only slightly affected the final arm angle at fracture strength as shown in Fig.

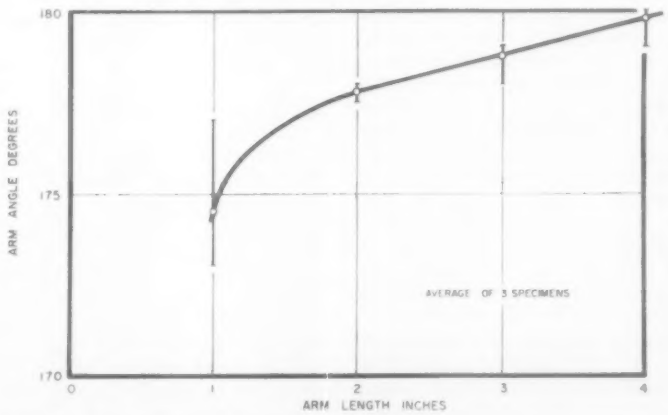

Fig. 15—Arm angle versus arm length at maximum joint strength

15 and the early stage of loading as shown in Fig. 10, but it did not affect the joint strength as shown in Fig. 9. The influence of arm length on the final arm angle at fracture strength and the early stage of loading was merely due to the differences in bending moment about the joints. During test, except for the specimens with zero length of arm, the arms of the specimen were pulled in opposite directions and a sharp bend formed gradually adjacent to the weld. From Fig. 15, it can be seen that the maximum difference in the included angle at maximum load between a 1 and 4 in. arm was only 5 deg. The difference in degree of cold work at this region could be considered negligible. As the strength of the joint in this test is lower than the longitudinal tensile strength of the rod, the joint strength would not be affected by any degree of cold work outside of the weld.

Conclusions

1. An inserted shim for certain weld joint geometries can serve as a projection to give a desired length of weld joint and uniform current distribution during welding.

2. An inserted shim projection having good solubility with the base material may lead to strengthening the weld joint.

3. When joint strength is important, the melting point of the inserted shim material should not be more than 150° F higher than that of the base metal.

4. The shorter the shim (within limits), the higher the joint strength and consequent uniformity of joint strength.

5. The length of arm of the test specimen does not affect the ultimate joint strength.

Acknowledgment

The authors wish to express their appreciation to Picatinny Arsenal, Dover, N. J., U. S. Army, for permission to publish this report. The authors also wish to thank Messrs. Frank H. Adolf, John Finn and Larry F. Dietz of Picatinny Arsenal for their guidance and assistance.

References

1. Harkins, F. G., "Spot Welding of Nickel and Nickel Alloys," THE WELDING JOURNAL, **29** (1), Research Suppl., 3-s to 12-s (1950).

2. Nippes, E. F., Pflugen, A. R., and Slaughter, G. M., "Seam Welding Monel Metal to Steel," *Ibid.*, **29** (3), Research Suppl., 134-s to 140-s (1950).

3. Thielsh, H., "Alloying Elements in Chromium-Nickel Stainless Steels," *Ibid.*, **29** (8), Research Suppl., 361-s to 404-s (1950).

4. Nippes, E. F., Gerken, J. M., and Maciora, J. G., "Projection Welding of 0.010-In. Steel Sheet," *Ibid.*, **29** (9) Research Suppl., 441-s to 449-s (1950).

5. Nippes, E. F. and Slaughter, G. M., "Seam Welding of Monel Metal," *Ibid.*, **30** (11), Research Suppl., 537-s to 544-s (1951).

6. Nippes, E. F., Savage, W. F., Ianniello, L. C., and Owczarski, W. A., "Spot Welding of a 12% Cr Martensitic Stainless Steel," *Ibid.*, **38** (9), Research Suppl., 360-s to 366-s (1959).

7. Witherell, C. E., "Some Factors Affecting the Weldability of the Cupro-Nickels," *Ibid.*, **39** (9), Research Suppl., 411-s to 416-s, (1960).

8. Keh-Chang Wu and Lewis, R. E., "A Study to Improve Weld Strength and Uniformity in a Continuous Rod Mat by Resistance Projection Welding," Watervliet Arsenal Technical Report, WVT-RI-6101-R.

EUROPEAN WELDING RESEARCH

By Gerard E. Claussen

BELGIUM

In its Issue No. 4 of 1960 the Belgian *Revue De La Soudure* contains the following articles:

• To increase the critical load at which the flanges of an I beam column fail by buckling, researchers at Liege University deposited weld beads along the edges of the flanges. The residual tensile stress in the beads raised the stress at which the flanges buckled. Other methods of introducing tensile residual stress besides welding also raised the buckling strength. Compressive residual stresses introduced into the outer edges of a bowstring bridge girder raised the buckling load by 26%.

SWEDEN

The January 1961 issue of *Svetsen* contains the following article:

• Measurements of triaxial residual stress through the thickness of a quenched cube of 2-in. steel plate showed that stress relief heat treatment at 1110° F for 5 hr lowered the residual stress substantially to zero.

Besides underbead cracks and microfissures, C. Pfeiffer believes there is a third type of hydrogen cracking. He calls this type hydrogen shrinkage cracking, and finds it in low-alloy steel weld metal deposited by low hydrogen electrodes. The cracks are perpendicular to the surface of the weld similar to those reported by P. Arnold in WELDING JOURNAL, 1957, p. 373-s.

USSR

Svarachnoe Proizvodstoe January 1961 contains the following:

• Three machines for testing the susceptibility of submerged-arc weld metal to transverse and longitudinal hot cracks are available in Russia. Each bends the plate on which the weld bead is being deposited. In one machine the rate can be varied from 0.02 to 2.3 deg per minute. A fourth machine tests for susceptibility to cold cracks by maintaining a static tensile stress of 43,000 to 86,000 psi on the welded joint for periods from 2 min to 50 hr. Several types of impulse and electromagnetic defectoscopes are available in Russia.

• Measurement of intergranular corrosion in $CuSO_4$ solution of Type 308 weld metals with 0.045 to 0.09% carbon showed that addition of 0.67% Cb provided the best results after reheating to 850–1400° F.

• The yield and tensile strength, reduction of area, and hardness of mild steel submerged-arc weld metal were plotted as functions of heat input and instantaneous cooling rate. The welds were made in slotted plates to avoid strain during cooling. The relations were plotted as curves, which showed that strength increased and ductility decreased as cooling rate rose. The experimental results exhibited considerable scatter.

• Multi-flame torches were designed in which the oxygen and acetylene mix after issuing from the tip. Flashback and water cooling are

(*Continued on p. 458-s*)

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Heat Treatment and Welding of 13% V - 11% Cr - 3% Al Titanium Base Sheet Alloy

Both pre-age cold rolling and duplex aging inprove as-received tensile properties, and flash annealing and magnetic stirring enhance weld properties

BY J. F. RUDY, F. A. CROSSLEY AND H. SCHWARTZBART

SUMMARY. A program on the heat treatment and welding of 0.093 in. B 120 VCA sheet is described; these operations were studied in terms of tensile properties, hardness, microstructure and TTT diagrams in an effort to arrive at mechanisms.

The effects of various degrees of cold work and post-working resolution treatment on aging response have been determined.

Aging experiments included both isothermal and duplex treatments. Isothermal treatments were carried out between 700 and 1000° F for durations of 2 to 400 hr. The duplex treatments consisted of an aging treatment similar to the isothermal treatments described above, followed by a "flash anneal" at 1000 to 1100 ° F for a duration of 5 to 160 min.

Both cold rolling, as a pre-age treatment, and duplex aging showed important advantages in tensile properties over the commercially popular solution-treat-and-age sequence.

Welding poses some difficulty in that, although the as-welded ductility is ample, on aging the ductility of the weld metal itself is considerably lower than the sheet material for corresponding aging times and strength levels. Duplex aging cycles gave more promising weld metal properties than did isothermal aging. Magnetic stirring, a weld deposition technique intended to refine the weld metal grains and to increase weld metal homogeneity, showed improved tensile properties in duplex-aged weldments.

Other weldment treatment modifications—including roll planishing, stress relieving, re-solution treatment, and partial pre-aging of the base metal—did not offer marked advantage in the final aged condition, although further experimentation is called for in some areas.

Introduction

The alloy of titanium with 13% V - 11% Cr - 3% Al has been called the all beta alloy. Titanium solidifies as the body centered cubic beta (β) phase and transforms to the close packed hexagonal alpha (α) phase at 1610° F. β phase can be stabilized to lower temperatures by additions of certain alloying elements. In the subject alloy, sufficient quantities of vanadium and chromium have been added to lower the transformation temperature (β-transus) to about 1325° F, diffusion is limited; hence the transformation is sluggish, and β can be retained at room temperature with moderate cooling rates from temperatures above the β-transus. The β phase thus obtained is metastable. Aging between 700 and 1000° F allows the transformation of a portion of the metastable β to the equilibrium low-temperature phases, α and $TiCr_2$. These phases, and the transition phase (ω) which occurs, cause changes in the microstructure of the alloy and a useful range of mechanical properties.

The aging of this alloy can best be discussed with reference to its time-temperature-transformation diagram of metastable β. Two published versions of this diagram appear in Fig. 1, after Rawe, *et al.*,[2] and Tanner.[3] They are not in exact agreement, and the identification of ω is tentative (Rawe, *et al.*, labeled it "ω?"); but taken together and assumed accurate they provide a useful guide for this discussion. In fact, the ability to explain the aging behavior in the present investigation in terms of these diagrams is partial verification.

Aging the alloy in the range 700 to 1000° F, after solution treatment (cooling from above 1325° F at a reasonable rate), causes an initial transformation of ω. While this early ω transforms to α, more ω appears. As α (which is lean in Cr and V) precipitates, β becomes richer in these elements until finally $TiCr_2$ precipitates. Thus the phase mixtures appear in the following sequence: $\beta \rightarrow \beta + \omega \rightarrow \beta + \omega + \alpha \rightarrow \beta + \alpha \rightarrow \beta + \alpha + TiCr_2$.

Aging for engineering utility has generally been accomplished by exposures in the temperature range 850 to 900° F for durations of less than 100 hr. Thus, according to the diagrams of Fig. 1, the observed strength variation is attributable to $\beta \rightarrow \beta + \omega \rightarrow \beta + \omega + \alpha$ transformations. The compound $TiCr_2$ also possibly contributes.

The mechanical properties of the aged alloy are largely a function of distribution and size of the transformation products ω and α. The nature of this precipitation depends on two factors:

1. The condition of the β phase (density of high energy sites) prior to aging.
2. The time and temperature of aging.

The variation of mechanical properties with the aging parameters (time and temperature) is discussed below for several pre-age conditions.

This heat treatment and welding study was conducted on 0.093 in. sheet except where otherwise noted.

Heat Treatment

Isothermal Aging Treatments

Effect of Prior Condition of β Phase. The heat treatment most widely used by industry is to age the material in the "as-received" condition. The "as-received" procedure has not been precisely defined, as this is proprietary, owing to the marked dependence of final properties on this procedure. However, it is known to be a solution treatment (β anneal) which follows cold or warm rolling. Heating to 1450° F for 20 to 30 min. followed by an air cool will serve as a nominal description of the solution treatment. Additional exposures at temperatures of 1400 to 1500° F (re-solution treatments) have an important bearing on aging behavior by furthering the process of "annealing-out" of high-strain-energy sites. Since these sites are

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Paper presented at AWS 42nd Annual Meeting held in New York, N. Y., during April 17-21, 1961.

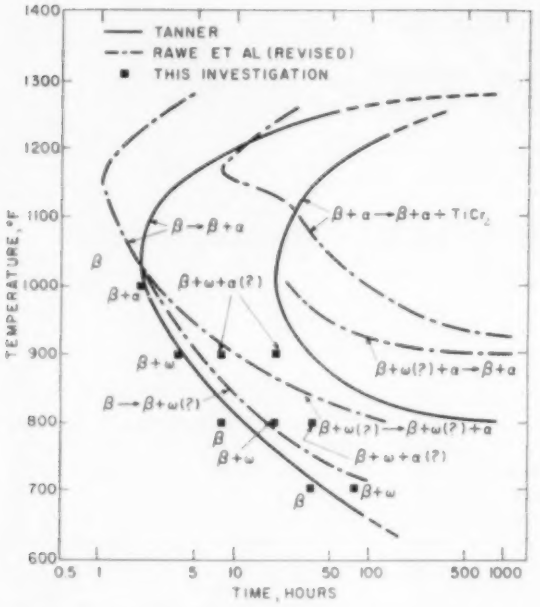


Fig. 1—Two published versions of the time-temperature-transformation diagram for B 120 VCA. Metallographic observations of this investigation are indicated

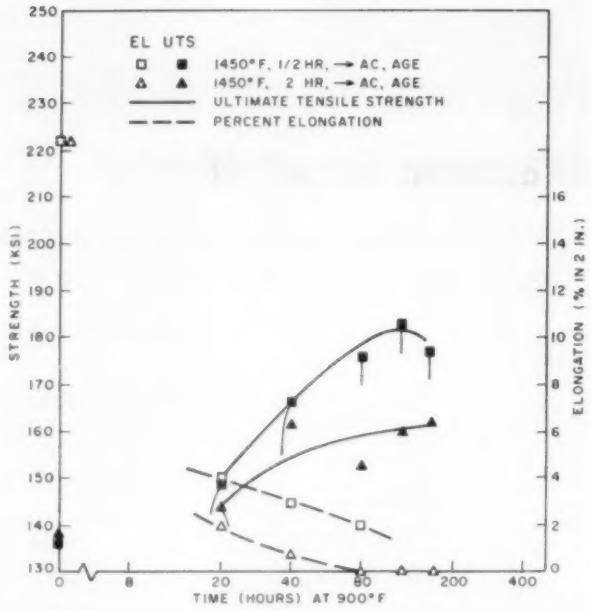


Fig. 2—Tensile properties vs. aging time for two re-solution treatments. Tails indicate yield strength

favorable locations for nucleation of the precipitate phase, re-solution treated material will have a different precipitate distribution. Thus, a logical order of presentation of aging characteristics is (*a*) re-solution treated, (*b*) "as-received," and (*c*) cold-worked to increasing degrees, this being the order of increasing density of favorable sites for nucleation.

The variation of tensile properties with time of aging at 900° F for *re-solution treated* sheet is plotted in Fig. 2. The lower strength plot was aged after re-solution at 1450° F for 2 hr, air cool, and the higher strength plot shows the aging behavior after a similar $^1/_2$ hr re-solution treatment. These tensile properties are not particularly attractive, compared to the appreciable elongation obtained at 137 ksi ultimate tensile strength in the solution-treated condition.

The variation of tensile properties with time of aging at 900° F for *as-received* material is plotted in Fig. 3. These data are scattered unless the particular points for each sheet are identified as shown. This gives a family of curves, all lying above those for the re-solution treated material shown in Fig. 2. Elongations are also higher, for a given strength level and aging time, for the as-received sheets.

Tensile property aging behavior for *cold rolled* sheets is shown in Fig. 4. The strength plots move toward higher strengths and shorter times as cold work increases. Elongation is also improved for a given strength level compared to as received material.

Figure 5 summarizes the aging behavior at 900° F for the various conditions of the β phase. The

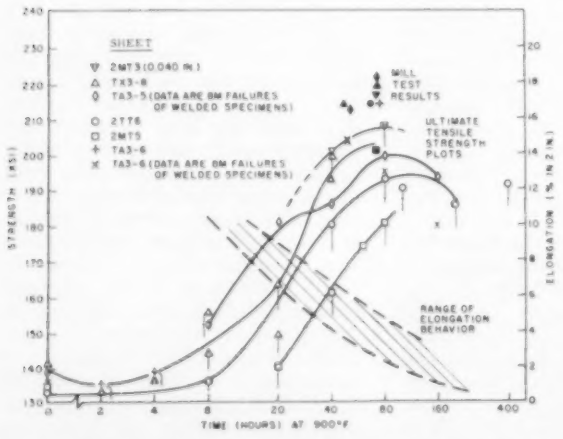


Fig. 3—Tensile properties vs. aging time for as-received sheets. Yield strengths are indicated by the tails of the ultimate strength points

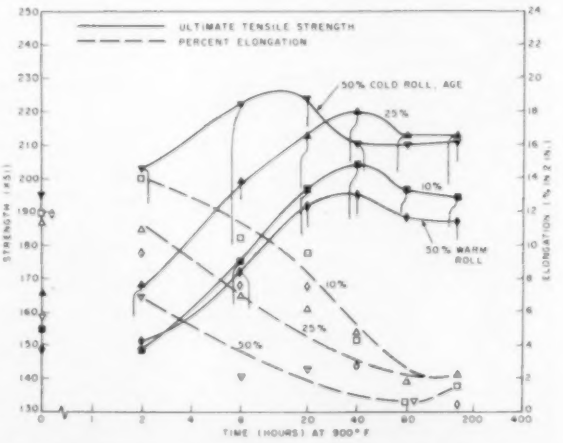


Fig. 4—Tensile properties vs. 900° F aging time for cold and warm rolled sheet

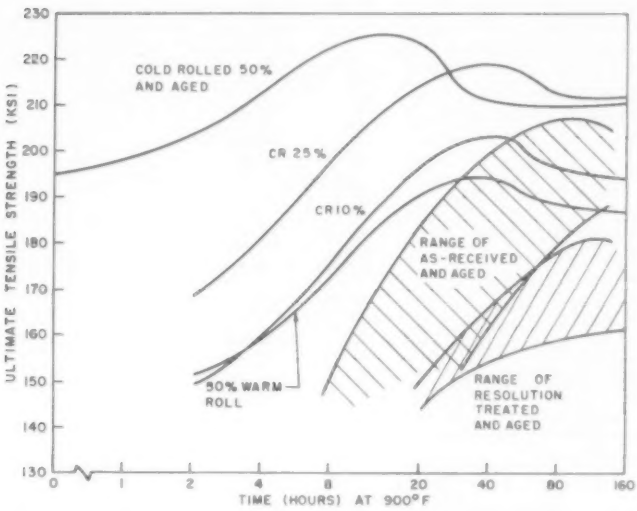


Fig. 5—Summation of 900° F aging behavior for re-solution treated, as-received, and rolled sheets

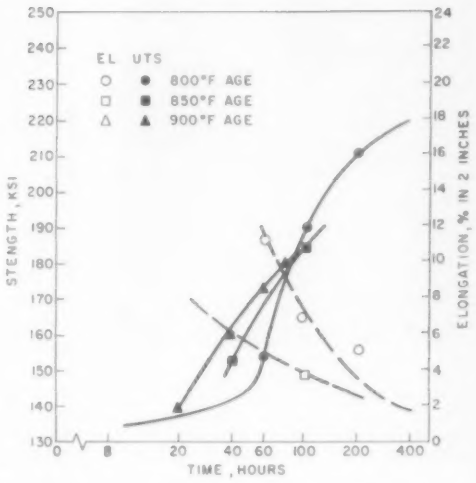


Fig. 6—Tensile properties vs. aging time-temperature for sheet 2MT5 (as-received)

tendency for higher strengths to be obtained with shorter aging times, as the strain-energy of the β lattice increases, is immediately apparent.

Uniformity of Aging Behavior. The foregoing observations introduce a discussion of the variation of aging response from sheet-to-sheet as shown in Fig. 3 for as-received material. Three of the six sheets represented came from the same ingot (2MT3, 2TT6, 2MT5) and differences in composition do not explain their relative behavior. The mechanical working and thermal solution treatment history, i.e., the condition of the β prior to aging, is a more likely possibility. Some observations which support this explanation follow:

1. The 0.040 in. sheet (2MT3), which presumably received more cold rolling than the other (0.065 in.) sheets, was one of the highest strength sheets.

2. Relatively minor, but consistent, dependence of aging behavior on location within a single sheet followed the same pattern as the variation of thickness. The edges of the sheets, which were reduced further than the center because of deflection of the rolls, aged to higher strengths.[1]

3. The microstructures during the early stages of aging (900° F, 1 hr) showed a greater density of subgrain boundaries in the faster aging sheets. Since subgrain boundaries are associated with lattice defects, this supports the assumed aging response—prior β condition relationship as the primary cause of non-uniform behavior.[1]

Effect of Temperature on Aging. The foregoing paragraphs have discussed the 900° F aging behavior of β phase after several pre-age treatments. The temperature of aging also influences this behavior. Figure 6 shows the variation of tensile behavior on aging at 800, 850 and 900° F of a sheet (2MT5) in the as-received condition. As expected, lower temperature treatments are slower to initiate changes, but greater strengths are achieved eventually. Better combinations of strength and elongation are obtained with 800° F than with 850 or 900° F aging treatments. Similar behavior is observed upon aging sheet which has been cold rolled 25%, as shown in Fig. 7. The strength curves show higher maxima at longer times as the aging temperature is lowered. Similar data were obtained for material reduced 10 and 50% by cold rolling.[1]

Summation of Tensile Properties Obtained by Isothermal Aging Treatments. The important measure of the desirability of a given heat treatment, in terms of tensile properties, is not strength or ductility independently, but the strength-elongation combination which can be obtained. Therefore, in order to sum-

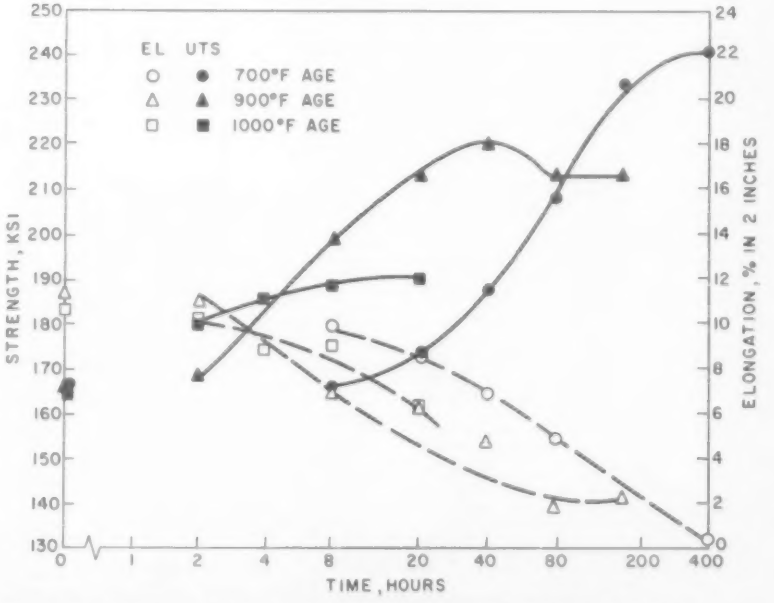


Fig. 7—Tensile properties vs. aging time-temperature for 25% cold rolled sheet

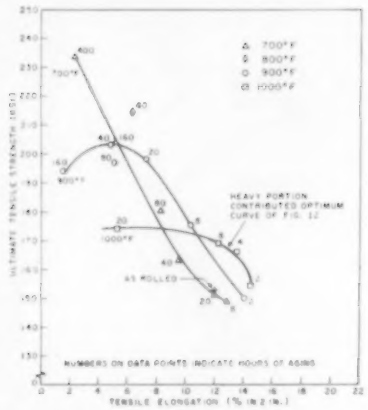


Fig. 8—Tensile properties obtained on aging 10% cold-rolled sheet

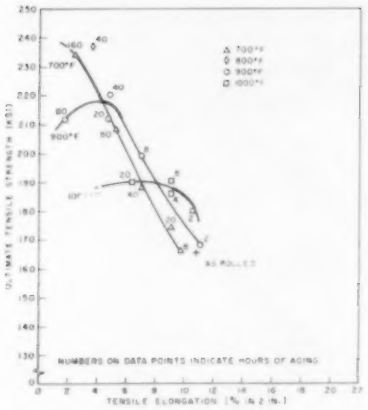


Fig. 9—Tensile properties obtained on aging 25% cold-rolled sheet

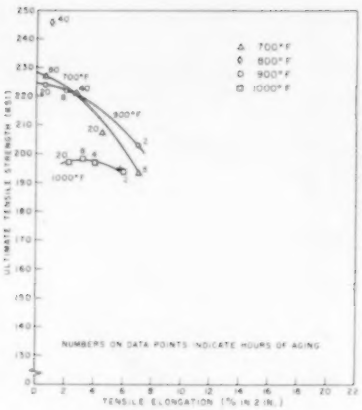


Fig. 10—Tensile properties obtained on aging 50% cold-rolled sheet

marize the tensile data in a form which facilitates such a comparison, plots of tensile strength versus tensile elongation are given in Figs. 8 through 12. Plotted in this manner, types of treatment which provide data toward the upper right-hand corner are superior to treatments which fall to the lower left.

As an example, Fig. 8 shows plots of tensile strength-tensile elongation of material which has been cold rolled 10% prior to aging at 700, 900 or 1000° F. The numbers on each point indicate hours of aging at the given temperature. In comparing the three curves, it is seen that 1000° F aging treatments of 2 to 8 hr give the highest elongation in the ultimate strength range of 155 to 170 ksi. This curve also suggests a practical criterion for overaging; i.e., the 20 hr treatment (1000° F), while showing a modest strength improvement over the 8 hr treatment, has so little ductility that its point lies considerably below and to the left of an apparent composite plot of optimum properties for this family of treatments consisting of the uppermost portion of each curve (say, a line running from point 160 ksi—14% to point 235 ksi—2%). In the strength range 175 to 200 ksi, treatments of 900° F for 8–20 hr appear to be most promising, while at highest strength levels, long time treatments at 700° F are required. Overaging occurs, as indicated, after approximately 40 hr of 900° F treatment of 10% cold rolled material.

Comparable data were obtained for 25% and 50% cold rolled material at the same aging temperatures. (Figs. 9 and 10). With increased cold work the plots move up and to the left toward 235 ksi, 2%. Overaging, as defined above, occurs at shorter aging times as cold rolling increases from 25 to 50%. For example, 8 to 20 hr at 900° F is beginning to overage material which has been cold rolled 50%.

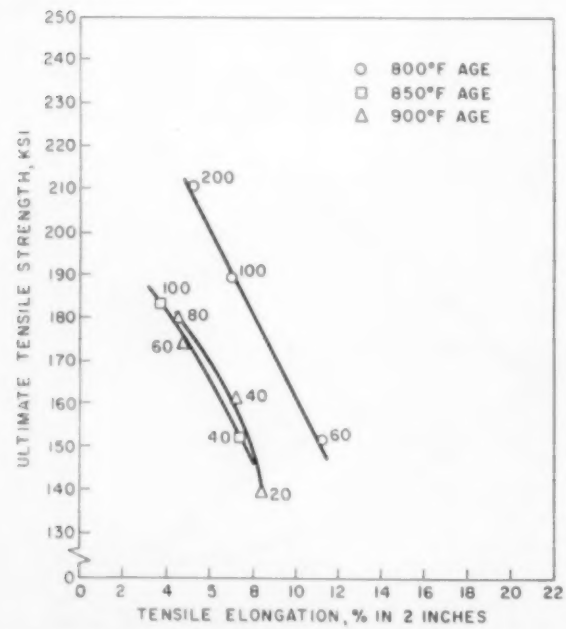


Fig. 11—Tensile properties obtained on aging sheet 2MT5 (as-received) at 800, 850 and 900° F

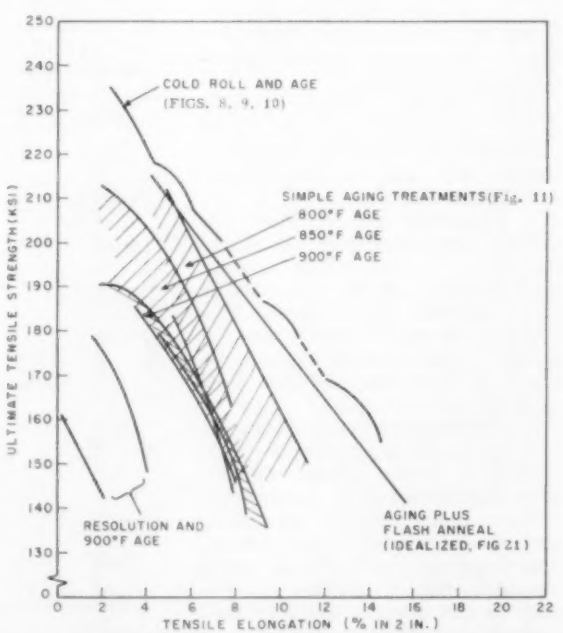


Fig. 12—Optimum tensile properties by types of treatments indicated

Fig. 13—Aged at 700° F for 40 hr from the as-received (solution treated) condition. The structure is (a'l) β phase. Oblique lighting. X 1000. (Reduced 25% on reproduction)

Fig. 14—Aged at 700° F for 80 hr from the as-received (solution treated) condition. The structure is β plus a mottled background (visible only under oblique lighting) which is suggestive of ω. Oblique lighting. X 1000. (Reduced 25% on reproduction)

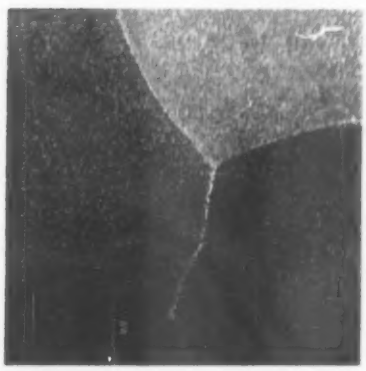


Fig. 15—Aged at 800° F for 40 hr from the as-received (solution treated) condition. This precipitate is visible under direct lighting and is tentatively identified as α. Some ω may also be present. Direct lighting. X 1000. (Reduced 25% on reproduction)

Figure 11 shows the strength vs. elongation relationships for aging an as-received sheet (2MT5) at 800, 850 and 900° F. The higher aging temperatures give less desirable tensile properties than the 800° F aging treatments, and all the data are inferior to the cold roll-and-age data discussed above. Resolution and age strength vs. elongation data, plotted in a similar manner, are shown to be appreciably lower than the as-received and the cold rolled aging results. The isothermal aging tensile data are summarized in Fig. 12. This plot summarizes strength-elongation combinations which can be obtained by the several types of heat treatment studies. The best properties were obtained by cold rolling prior to aging; next was aging from the as-received (solution treated) condition with temperature of aging an important parameter; and finally, the poorest tensile properties were obtained with a re-solution treatment prior to aging. These observations point-out the importance of pre-age processing. The aging plus flash annealing plot will be discussed below.

Microstructural Observations. The change of tensile behavior with aging treatments results from the decomposition of β to ω, α, or possibly to the compound $TiCr_2$. The dependence of these tensile properties on the mechanical and thermal treatments imposed, can be correlated with the microstructures. Figure 13 shows the typical β grain structure. When the aging time is extended to 80 hrs at 700° F, the fine mottled structure, indicative of the occurrence of the precipitate phase ω is observed under oblique lighting (Fig. 14) but not under direct lighting. This corresponds to the "ω?" of Rawe, *et al.*—see Fig. 1.

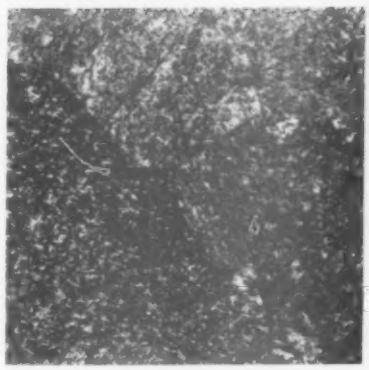


Fig. 16—Aged at 900° F for 20 hr from the as-received (solution treated) condition. Tentative identification per Fig. 15, $\beta + \omega + \alpha$. Direct lighting. × 1000. (Reduced 25% on reproduction)

At 800° F this mottled structure appears after only 20 hr, and a more developed precipitate, which is visible under direct lighting, is visible after 40 hr (Fig. 15). The structure consists of fine α in a β matrix according to the TTT diagram.

At 900° F, the mottled structure indicative of ω appears after 4 hr. A heavier precipitate, visible under direct lighting, and hence identified as α, is visible after 8 hr. The TTT diagram, based on X-ray diffraction data, predicts the presence of ω along with α after 8 hr. This precipitate is more developed after 20 hr (Fig. 16).

At 1000° F, the precipitate forms after only 2 hr and is appreciably larger (Fig. 17).

When the material is re-solution treated prior to aging, the precipitate is considerably coarser for a given aging treatment than for material aged from the as-received condition. Conversely, cold rolling prior to aging causes the precipitate to be considerably finer.

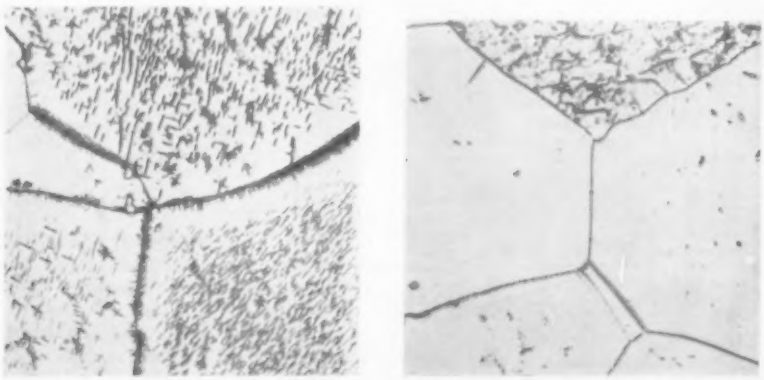


Fig. 17—Aged at 1000° F for (left) 2 hr and (right) 8 hr from the as-received (solution treated) condition. Tentative identification, $\beta +$ Coarse α. Direct lighting. × 1000. (Reduced 25% on reproduction)

Duplex Aging Treatments

Since the character of the β decomposition product is a function of the temperature of transformation, products can be obtained by a combination of transformation temperatures which cannot be obtained isothermally. The combination (or duplex) age which has been extensively investigated is an initial aging treatment, with time-temperatures similar to those of isothermal aging, followed by a short time, higher temperature "flash anneal." Three flash annealing temperatures were employed: 1000, 1050 and 1100° F—with time of exposure varying from 5 to 160 min. The effect of flash annealing depends on the preceding aging treatment, i.e., of the relative size and distribution of the ω and α phases.

Figure 18 shows curves of strength and elongation vs. flash annealing time, for various temperatures, of the flash anneal after an initial age of 800° F, 60 hr. The 1000° F treatments will be discussed, since they give somewhat better tensile properties and the changes are spread out over a longer period of time. It can be seen that the initial effect of the 1000° F (5 min) exposure is to increase the strength and to decrease the ductility. (This is counter to the expected effect of an "anneal"; but the tendency is consistent throughout the duplex treatments studied.) After the initial increase, strength falls (10–20 min) and remains relatively low (~ 145 ksi) for a period (20 to 80 min), and finally starts to increase (160 min. at 1000° F). The tensile elongation plot is essentially a mirror image of the strength plot.

Similar behavior is observed for flash annealed specimens which have been aged for longer times (100, 200 and 400 hr) at 800° F, as summarized in Fig. 19. These curves show the initial development of a strength maximum in 5 to 10 min, followed by a strength reduction, and a final moderate strength increase after 160 min. The longer the aging time, the smaller is the relative increase in strength for the initial strength maxima upon flash annealing at 1000° F. The curve for prior aging at 800° F for 400 hr shows only a plateau, rather than a maximum during this initial period.

Similar data for material aged at 900° F are summarized in Fig. 20. The strength variations for 900° F aged material are of lesser magnitude than those for 800° F aged material, but several characteristic similarities can be observed between the two families of curves. The initial aging strength maximum is still in evidence on the 900° F, 60 hr curve. The 900° F, 100 hr curve shows this maximum displaced to 10 min. at 1000° F, which does not parallel the family of curves. The 200 and 400 hr plots can be compared to the "initial plateau" behavior for the 800° F, 400 hr plot of Fig. 19. A second strength increase, merely suggested by the 160 min strength increase of Fig. 19, appears on the 60, 100 and 200 hr plots of Fig. 20 with maxima at 20 to 40 min.

This rather complex tensile behavior, which the material exhibits on flash annealing of an aged specimen, can be rationalized in terms of the phases ω, α, and $TiCr_2$ which are involved. After the "aging" treatment at 800 or 900° F for 60 to 400 hr, the microstructure contains ω and α precipitates in a β matrix. The earliest phase to appear on aging is ω; which is finally replaced by α at longer times. Thus, at lesser times and temperatures of aging, ω is more important in determining mechanical properties than α. As aging progresses, the influence of α becomes predominant, and possibly some $TiCr_2$ will be present. Consider the flash annealing of a specimen which has been aged at 800° F, 60 hr. This sample contains ω and α. On heating to 1000° F, ω can exist only for a very short time (the TTT curves are inconclusive concerning ω at 1000° F) and must transform to α or retrogress to β. If $\omega \rightarrow \beta$ occurred, the strength would be expected to decrease and the elongation to increase. Since just the opposite change is observed, it is suggested that $\omega \rightarrow \alpha$ reaction is predominant during the early "5 min maximum" stage of flash annealing, and that the fine α so formed is a more effective strengthener than the ω which it replaces.

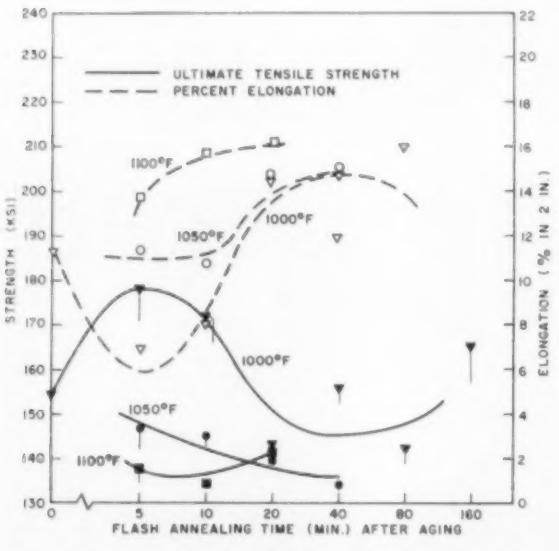


Fig. 18—Tensile properties vs. flash annealing time after aging 800° F, 60 hr. Tails on strength plots show yield strengths (0.2% offset)

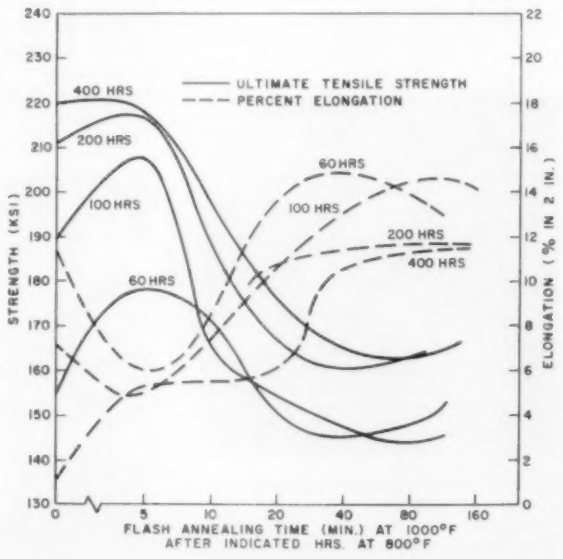


Fig. 19—1000° F flash annealed tensile properties after different 800° F aging treatments

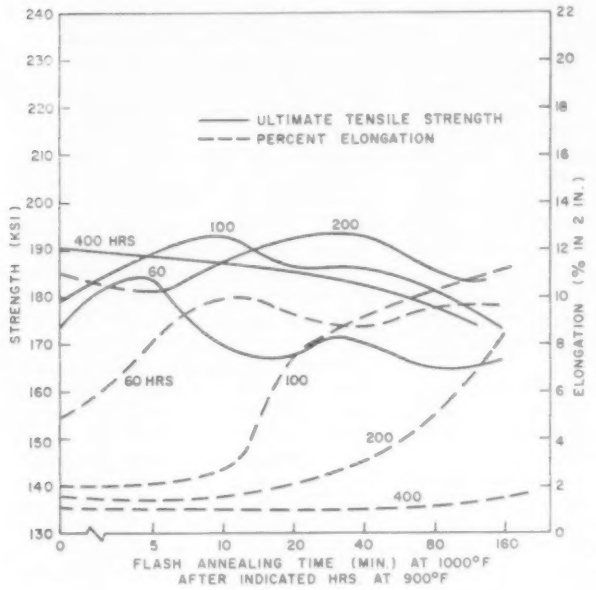


Fig. 20—1000° F flash annealed tensile properties after different 900° F aging treatments

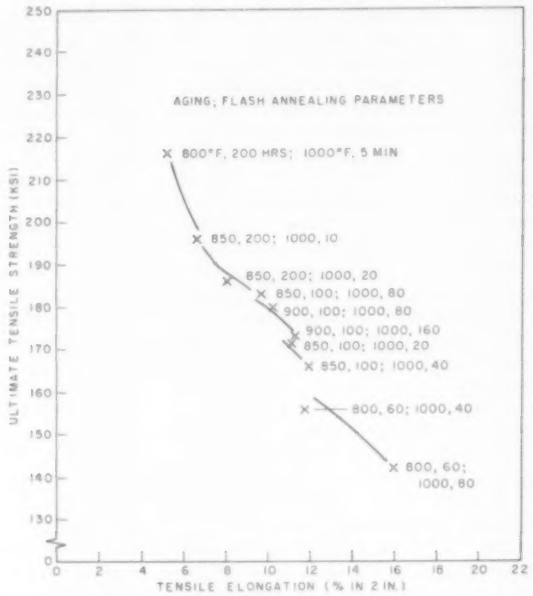


Fig. 21—Tensile properties obtained with optimum age-plus flash anneal (duplex aging) treatments. The segments of curves which make up this plot are taken from Rudy, *et al.*[1]

As the low temperature range aging times and temperatures increase, the ω-to-α ratio decreases, and the $\omega \rightarrow \alpha$ reaction which is expected during the early stage of flash annealing becomes less important relative to the as-aged condition. This may explain the observation that the 5 min strength maximum on the flash annealing plots flattens to a plateau as aging time-temperature increases (Figs. 19 and 20).

Returning to the 800° F, 60 hr plot of Fig. 19, the decrease of strength after 10 to 20 min. at 1000° F is considered to be due to the coalescence and coarsening of α already present. The strength remains at this level until, after 160 min, a second strength increase is indicated. On the 900° F age plus flash anneal plots, this second maximum occurs at 20 to 40 min. This second strength increase can be attributed to the formation of $TiCr_2$ from the enriched β matrix.

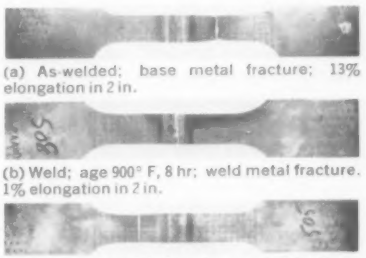
Strength vs. tensile elongation relations obtained by various duplex aging treatments are shown in Fig. 21. Since the strength and elongation vary in a complex manner with time of flash annealing, these plots tended to skip and zig-zag as time increases. However, taking the better tensile property combinations of the whole duplex aging type of treatment, and entering these on a single plot does give useful information. The better tensile properties at the 140-150 ksi ultimate strength level are obtained with low temperature-short time ages followed by long time flash anneals. At the high strengths (200 to 220 ksi), low temperature-long-time ages followed by short time ("initial maximum") flash anneals are required. Between these extremes a wide variety of duplex aging combinations are in evidence.

If the plot of optimum duplex aging tensile properties (Fig. 21) is approximated by a straight line, and this line is entered on Fig. 12 as indicated (aging plus flash anneal), the resulting summation plot compares the optimum tensile properties which can be obtained with each of the several types of treatments evaluated. A final summation of heat treatment results, in order of decreasing tensile properties, is shown to be: (*a*) cold roll and age, (*b*) duplex age (age plus flash anneal) the as-received material, (*c*) age the as-received sheet at 800° F, (*d*) at 850° F, and (*e*) at 900° F, and poorest results obtain for (*f*) age the re-solution treated sheet.

Welding

Experimental Approaches

In order to make most efficient use of the tensile properties of this alloy in an engineering structure, it is desirable to obtain properties of the weld area comparable to those of the base metal. This means either that the aging response of the weld area zones should parallel that of the base metal, or that a complex treatment of the weldment as a whole should be devised such that weld zone and sheet may arrive at a compatible combination of properties. Both of these approaches —direct parallel treatments and

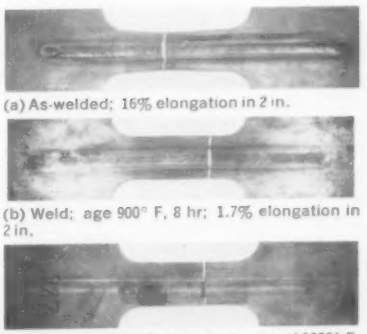


(a) As-welded; base metal fracture; 13% elongation in 2 in.

(b) Weld; age 900° F, 8 hr; weld metal fracture. 1% elongation in 2 in.

(c) Weld; age 900° F, 8 hr; base metal fracture; 5.5% elongation in 2 in.

Fig. 22—Typical transverse tensile fractures



(a) As-welded; 16% elongation in 2 in.

(b) Weld; age 900° F, 8 hr; 1.7% elongation in 2 in.

(c) Weld; age 900° F, 8 hr; flash anneal 1000° F, 40 min; 4.5% elongation in 2 in.

Fig. 23—Typical longitudinal tensile fractures

complex treatments—have been the subject of experimentation.

The weld joint tensile properties were determined in two directions of loading: transverse to the direction of welding as shown in Fig. 22, and longitudinal to the direction of welding as shown in Fig. 23. These two tests are complementary, since the transverse test gives the stress carrying ability of the weakest zone (assuming uniform cross section), and the longitudinal test measures the ability to plastically deform of the most strain sensitive zone, but does not give stress information for each zone. Figures 22 and 23 illustrate the problem which is encountered in attempting to utilize weldments of this material in the aged condition. In the as-welded condition (base metal is "as-received"), the transverse specimen shows the weld zones to be sufficiently strong to cause the fracture to be located in the base metal portion of the specimen (Fig. 22), and the longitudinal specimen shows that all the zones are able to elongate appreciably (Fig. 23). However, when the weld specimen is subjected to only a moderate amount of aging (900° F, 8 hr), the fracture in the transverse specimen sometimes occurs in the weld metal (Fig. 22), and the longitudinal fracture indicates that some zone across the weld is very sensitive to strain (Fig. 23).

A more complete presentation of the transverse and longitudinal behavior as a function of aging after welding appears in Fig. 24 and 25. The transverse tensile property plots (Fig. 24) are similar to those for aging of base metal. For example, the strength and elongation plots for base metal fractures in 900° F aged material are comparable to the sheet metal data for heat TX3-8 presented in Fig. 3. The elongations for *weld metal* fractures, however, are much lower over the whole range of aging times. After 80 hr, all fractures were observed to be in the weld metal zone. No appreciable improvement in transverse weld tensile properties was obtained with lower aging temperatures of 850 and 800° F.

The longitudinal weld tensile data are shown as a function of aging time for various temperatures in Fig. 25. The elongations are generally low except for the as-welded condition. Also, strength becomes very erratic after aging for 20 hr or more, probably owing to the tendency for premature failure to be initiated in a locally overloaded area which is sensitive to strain. These fractures initiated in the weld metal, as determined from fracture appearance.

Thus, the weldability problem is defined. The weld metal strength varies with aging time in a manner which is very similar to the base metal, i.e., the strength match of an aged weldment is satisfactory. The problem is that the ability of the weld metal to plastically deform is drastically limited, when the weldment is aged to an extent necessary to obtain even a modest increase in ultimate tensile strength. Working and thermal treatments which were studied for the purpose of improving the ductility in aged weld metal are discussed below.

Working and Thermal Treatments

Duplex Aging After Welding. In the heat treatment study of sheet material it was demonstrated that a flash anneal—say at 1000° F—resulted in improved properties when applied to material aged at 800 to 900° F. The effect of duplex aging on the properties of weld metal is, therefore, of interest. The transverse tensile behavior as a function of aging time at 900° F, with the aging treatment followed by a flash anneal at 1000° F, is shown in Fig. 26. The strength data for the flash annealed specimens are similar to those for simple aged specimens. However, some of the tensile elongation data show promise of improved ductility in the weld metal itself. This is shown more clearly by the longitudinal tensile data of Fig. 27. After 40 and 80 hr at 900° F, flash annealing improves the strength of the specimen. The ability of the whole specimen to carry greater load is considered to be due to an improvement in the ductility of the most strain-sensitive zone. When this strain-sensitive zone—presumably the weld metal—is able to strain to a greater extent, more load is assumed by the base metal and the longitudinal specimen strength is observed to increase.

While the duplex aging treatment gave an improvement in weld metal ductility, the measured 2% elongation (Fig. 27) is still marginal at best, and further improvements are desired. A number of complex welding, heat treatment, and mechanical treatment combinations

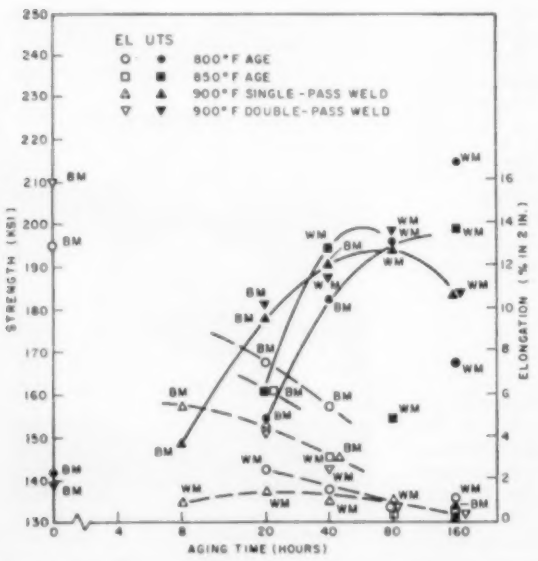


Fig. 24—Tensile properties of aged transverse weld specimens

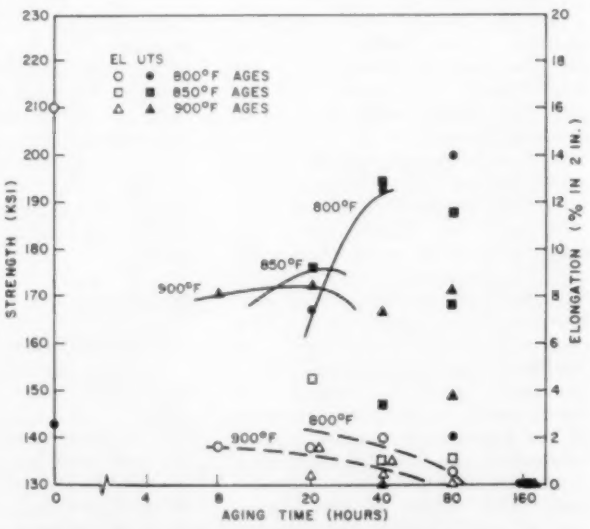


Fig. 25—Tensile properties of aged longitudinal weld specimens

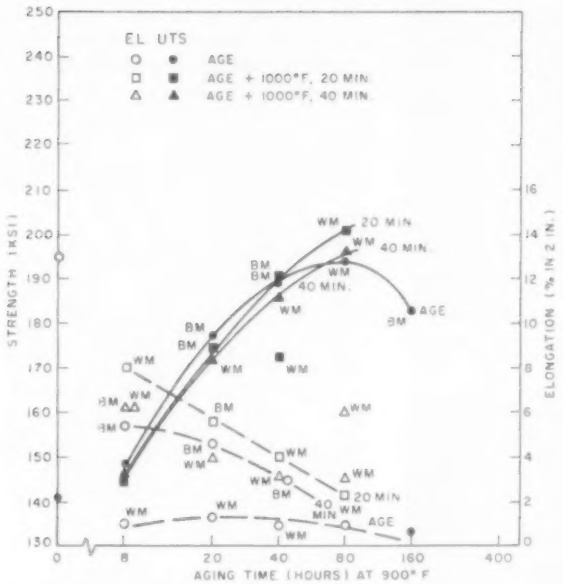


Fig. 26—Tensile properties of transverse weld specimens aged and flash annealed

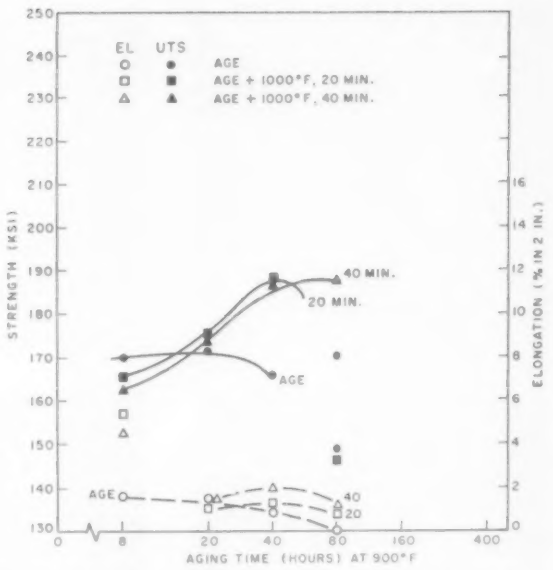


Fig. 27—Tensile properties of longitudinal weld specimens aged and flash annealed

were evaluated for the purpose of obtaining improved ductility in the heat treated weld metal. These experiments are reported below.

Post-Weld Thermal Treatments. The processing sequences of welding as-received (solution treated) sheet, and either stress relieving (1000° F, 2 hr) or re-solution treating (1450° F, ½ hr) before aging, were investigated. Evaluation was by longitudinal and transverse tensile testing. Neither treatment improved the aged tensile properties; in fact, weld metal ductility is considerably reduced by the post-weld stress relieving and resolution treatments, with and without subsequent aging. Re-solution is more harmful than stress relieving if the weldment is to be aged. However, resolution without aging retains some ductility and may be of interest as a stress relief if the material is to be used at the as-received strength level.

Mechanical Working. Since cold rolling was found to improve the aged tensile properties of the base metal, similar treatments in conjunction with welding and aging are of interest. Two variations were studied: cold rolling the weld bead only (roll planishing) prior to aging, and cold rolling the base sheet prior to welding and aging. For the roll planishing experiments, weld beads were made with a 20% build-up; these beads were rolled until flush with the base metal. The rolled beads were observed to have heavy surface lines which can be mistaken for cracks. However, on testing the as-rolled beads in the longitudinal direction, appreciable strength and elongation were observed and the fractures did not occur at these surface markings. The longitudinal tensile behavior on aging is very similar to the properties obtained for material welded from the as-received condition. The specimen has differing tensile behavior across the weld zones, because the weld bead has been cold rolled. When the base metal yields, therefore, the stress on weld metal increases and fracture occurs at a moderate specimen average stress.

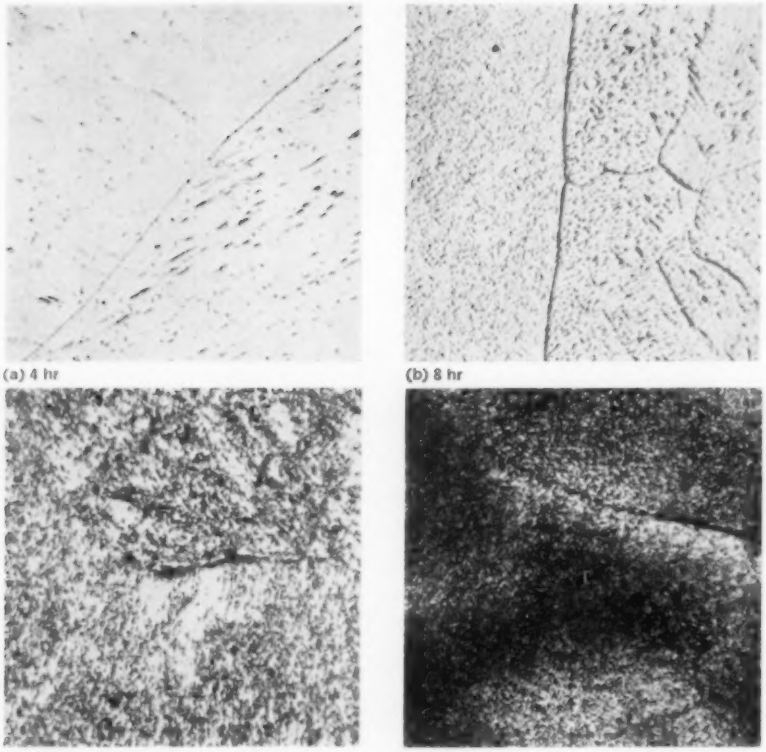
The second cold rolling sequence—cold roll, weld and age—did give some improvement in longitudinal tensile properties if the aging time is held to less than 20 hr at 900° F. The base metal being cold rolled responds faster than the weld metal; strengthening is obtained before the weld metal starts to age. For example, 155 ksi ultimate tensile strength was obtained after 4 hr, and 180 ksi was obtained after only 8 hr at 900° F. At 20 hr and more, however, the weld metal itself starts to age, and strength becomes erratic and ductility is low. Flash annealing increases the tensile elongation appreciably after 4 and 8 hr aging.

The transverse tensile properties of specimens subjected to a cold roll, weld and age sequence were very similar to the data of Fig. 24 for welded and aged material. All fractures occurred in the weld metal when the base metal had been cold rolled.

Age, Weld, Further Age. The specimen condition wherein the base metal has attained a more advanced stage of aging than the weld metal, which was shown to be of advantage under the longitudinal loading of cold rolled, welded and aged specimens as reported above, can be obtained by a preage, weld, and final age sequence. Several such sequences were evaluated involving preaging for 10, 20 or 40 hr at 900° F. The most promising of these was 40 hr pre-age, weld and age at 900° F for 20 hr. This gave 180 ksi in longitudinal tension, but elongation was a low 2%. This treatment, however, gave appreciably better longitudinal tensile properties when followed by a flash anneal. The sequence of age 40 hr at 900° F, weld, age 2 hr at 900° F and flash anneal, gave 157 ksi and 9% elongation. Increasing the post-weld aging time to 8 hr dropped the elongation to 2% with no appreciable increase in strength.

The transverse tensile data, as expected, showed weld metal fractures at strengths expected of the particular weld metal aging treatments (Fig. 24).

Cold Roll, Weld, Cold Roll, Resolution, Age and Flash Anneal. An attempt was made to obtain a homogeneous weldment in a condition for aging which approximates the "as-received" condition of the base metal. This included cold rolling the base metal, welding and cold rolling the weld metal, then solution treating and aging. The tensile property results of this com-



(a) 4 hr (b) 8 hr

(c) 20 hr (d) 160 hr

Fig. 28—Microstructures of weld metal after aging at 900° F for indicated times. (a) and (b) Oblique lighting; (c) and (d) direct lighting

plex treatment were not as satisfactory as the simple weld, and age sequence from the as-received condition.

Magnetic Stirring. The foregoing weld metal experiments have involved mechanical and thermal variations performed on the base metal or on the weld metal after deposition. In each case, gas tungsten-arc welding was applied as a bead-on-plate; weld deposition was an experimental constant.

Variation of the weld metal deposition procedures constitutes an additional category of means for improving the mechanical properties of the weldment. Only certain aspects of the weld bead are amenable to change through procedural variations. For example, sheet aging experiments have shown the deleterious effect of "oversolutioning," suggesting the need for a given distribution of nucleation sites (Fig. 5); this distribution is enhanced by mechanical working of the β phase and is reduced by too much homogenization at elevated temperatures. No amount of variation in deposition procedure will alter the fact that the weld metal is an as-cast structure with nucleation sites and discontinuities which are particular to a casting and not to a rolled structure. However, differences in the as-cast state can be obtained through deposition variation, particularly as regards such factors as composition homogeneity and grain size. Both of these factors are applicable to the weld metal problem, since the weld metal grains are much larger and the homogeneity is much lower than in the base metal.

Recent experiments have demonstrated that stirring an arc melted pool is an effective means of obtaining grain refinement.[4] The stirring is caused by the "motor force" which results from the interaction between the current paths and a superimposed alternating polarity magnetic field. The tensile properties of aged welds produced with this technique are as follows. Transverse tensile behavior is similar to that for conventional welding. When tested longitudinally, however, better strengths and elongations are achieved with the stirring technique. For example, after 80 hr at 900° F plus flash anneal, the stirred weld specimens developed 200-205 ksi with $1\frac{1}{2}$ to 2% elongation. The comparable unstirred welds gave erratic strength values suggesting very low ductility.

Summation, Weld and Heat Treat. The program of evaluation of heat treated weldments has shown that the as-deposited weld metal tensile properties very nearly match those of the as-received (solution treated) base metal sheet. The primary weldability problem with this alloy is introduced when it becomes necessary to age the weld metal to a higher strength level in order to take full advantage of the aged properties of the sheet itself. When such heat treatments are applied to the weld metal, its strength responds in a manner which is approximately parallel to the base sheet; but ductility of the weld bead is much lower, for a given strength level or aging treatment. The reason for this difference in aging behavior is not known. There are, however, several observations which can be made which may have some bearing on the problem.

The welds in the as-deposited condition contain a precipitate, which is different from any which appears during the aging of the base metal. This precipitate persists during the early stages of aging; it either disappears or is obscured when ω and α precipitation becomes highly developed. This precipitate may have some bearing on the tensile elongation behavior but this has not been established. An example of the precipitate is shown in Fig. 28a, with the superimposed α precipitate shown in Figs. 28b and c.

The aging behavior of the weld metal is at least partially attributable to the fact that the as-cast structure is "oversolutioned." The aging behavior of the base metal has been shown to be strongly dependent on the prior working and thermal history. However, the weld metal precipitate formed at 900° F in 20 hr (Fig. 28c) is not so coarse as that of similarly aged re-solution treated base metal. Therefore, oversolution treating does not explain the problem in the same terms that re-solution treatment is deleterious.

Large grain size and chemical inhomogeneity may be contributory factors. The large grains are evident in all the photomicrographs of Fig. 28 and the nonuniform aging pattern of Fig. 28d is evidence of dendritic segregation. The improvement observed by magnetic stirring suggests that grain size and/or segregation could be the problem.

A statement of the aged properties, which can be obtained in weldments by incorporating the variations investigated in this program,

can best be made in terms of the longitudinal tension test. This test is critical because it measures ability of the weld metal to elongate, an ability which is found wanting in the general case. Figure 29 is a plot of strength vs. elongation in longitudinal tension and serves as a convenient means of comparing the several types of procedures. The plots may be compared with Fig. 12, a similar summation of base metal aging behavior under the several types of treatment. Figure 29 does not contain all the longitudinal test results because the cluster of data in the low-ductility portion becomes confusing. However, it is interesting to discuss the longitudinal data which are more promising, i.e., those which fall near, or to the upper right of, an arbitrary line joining point 150 ksi, 7% to point 210 ksi, 2%:

1. As-welded plus roll planish (*148 ksi, 6.8%*). This no-age point appears promising, but attempts to increase the strength by even a short-time aging treatment causes a marked loss of ductility. For example, 900° F, 4 hr gives 161 ksi with only 1.8% elongation, and further aging continues in that direction. Unfortunately, flash annealing was not investigated as an addition to these treatments. Judging from the benefits obtained by flash annealing after other treatments, promising combinations may be expected.

2. Weld, age 900° F for 8 hr, followed by flash annealing at 1000° F for 20 min (*166 ksi, 6.5%*) or for 40 min (*163 ksi, 4.5%*). The same aging treatment, omitting the flash anneals, gives 171 ksi with only 1.8% elongation. Also, if the aging is allowed to progress further—say, for 20 hr—these flash annealing treatments do not restore ductility to the same extent. For example, 900° F, 20 hr gives 174 ksi, 1.5%; when this treatment is followed by flash annealing, comparable strengths are obtained with still only 1% and 1.5% elongation.

The flash annealing treatment is definitely of advantage as will be apparent in the following discussion concerning more complex treatments.

3. Welding with the magnetic stirring technique followed by a number of duplex aging treatments gives data falling close to this line:

a. For example, weld (magnetically stirred), age 900° F, 8 hr, flash anneal 1000° F, 40 min gives *164 ksi with 6%*. The same treatment omitting the flash anneal results in low (1.2%) elongation.

b. Weld (magnetically stirred), age 900° F, 20 hr, flash anneal 1000° F for 20 or 40 min gives a strength of *178 ksi with 3 and 4% elongation*, respectively. These data, compared with item 2 above, directly illustrate an improvement obtained by the stirring technique. Again, the flash anneal is necessary for adequate ductility.

c. Weld (magnetically stirred), age 900° F, 40 hr, flash anneal as before gives strengths of *195 and 191 ksi, respectively, with 3% elongation*. Without the flash anneals, the tensile properties are 184 ksi with 0.7% elongation.

d. Weld (magnetically stirred), age 900° F, 80 hr, flash anneal 1000° F, 20 min gives *207 ksi with 2% elongation*. Without flash annealing, the specimen failed at only 140 ksi with a measured 1% elongation.

4. Cold Roll (10%), weld, age, flash anneal. The treatments under items 1 to 3 above give weld metal strengths which are comparable to base metal. By cold rolling the sheet prior to welding, its aging response is enhanced. Then short aging times will cause the sheet to become aged while the weld metal remains unaged. When loaded in the longitudinal direction, the strength of the cold-rolled and aged base metal can be utilized without premature failure being initiated in the strain-sensitive weld metal. Examples of tensile properties obtained by this procedure employing 900° F aging are: 2 hr, *149 ksi, 5.5%*; 4 hr, *155 ksi, 5.5%*; and 8 hr, *181 ksi, 10%*. Examples of tensile properties obtained by 900° F aging followed by flash annealing at 1000° F for 20 min are: 2 hr age, *147 ksi, 9%*; 4 hr age, *151 ksi, 13%*; and 8 hr age, *169 ksi, 8.5%*.

Longitudinal tensile specimens receiving longer aging times (20 hr), without benefit of flash annealing, failed with low elongation (186 ksi, 1.5%). This behavior suggests that the weld metal itself becomes aged, leading to brittle fracture of the specimen.

Conclusions

This investigation has covered two separate but interdependent areas: the thermal and mechanical

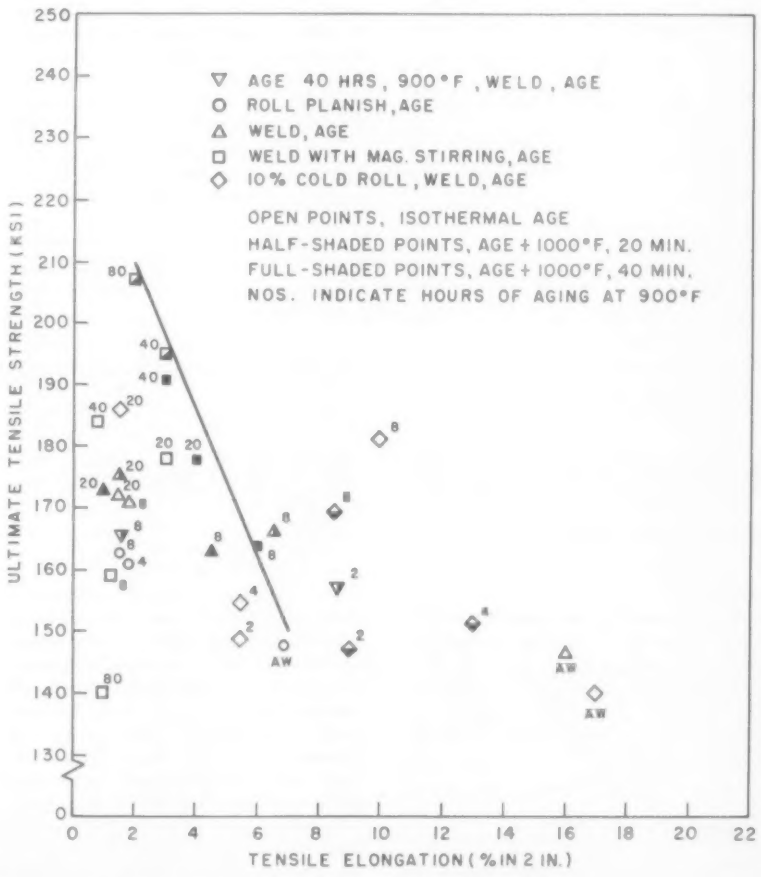

AGE 40 HRS, 900°F, WELD, AGE
ROLL PLANISH, AGE
WELD, AGE
WELD WITH MAG. STIRRING, AGE
10% COLD ROLL, WELD, AGE
OPEN POINTS, ISOTHERMAL AGE
HALF-SHADED POINTS, AGE + 1000°F, 20 MIN.
FULL-SHADED POINTS, AGE + 1000°F, 40 MIN.
NOS. INDICATE HOURS OF AGING AT 900°F
ULTIMATE TENSILE STRENGTH (KSI)
TENSILE ELONGATION (% IN 2 IN.)
AW

Fig. 29—Longitudinal weld tensile properties obtained with various procedures

treatment of B 120 VCA (13% V - 11% Cr - 3% Al) titanium alloy sheet, and the incorporation of heat treatment principles into the processing of weldments.

Heat Treatment

Isothermal aging at 900° F of as-received (mill solution treated) gave tensile properties which varied between 9% elongation at 135 ksi ultimate tensile strength to 4% at 185 ksi, depending on time of aging and on the aging response of the particular sheet. Elongation values can be improved, for a given strength level, by reducing the aging temperature to 800° F, but increased aging times are required. The range of optimum tensile properties with 800° F aging treatments varies between 11% elongation at 145 ksi to 5% at 210 ksi.

Re-solution and stress-relieving treatments of the as-received sheet are deleterious to the aged properties.

Improvements in elongation values at a given strength level, and in uniformity of aging response, can be obtained by cold rolling the as-received material prior to aging. Combinations of cold work (10% to 50% reduction) and age (700 to 1000° F; 2 to 400 hr) gave tensile properties which varied between 14% at 160 ksi and 3% at 230 ksi. These tensile properties were the most attractive obtained in the program.

Elongations within 1 to 2%, at a given strength level, of those obtained by cold roll and age combinations, were obtained by duplex aging of as-received sheet, i.e., age at 800 to 900° F for 60 to 400 hr followed by flash annealing at 1000° F for 5 to 160 min.

It should be understood that the ranges of tensile properties reported above for each type of treatment are obtained only when optimum treatment parameters are employed.

The above aging observations can be explained in terms of microstructure and of the transformations of β to ω, α and $TiCr_2$ according to published TTT diagrams.

Welding

In the as-welded condition the weld zone tensile properties are very similar to the as-received base metal, i.e., 130 ksi with 18–20% elongation. However, in the aged condition tensile elongation is considerably lower, for a given strength level, than the parent sheet. The elongation is improved by flash annealing and by a welding technique variation which employs magnetic stirring.

Other procedural variations offered no advantage unless the service loading conditions are such that somewhat lower strengths can be tolerated in the weld metal than in the parent sheet (for example, tension loading parallel to the weld bead). Promising procedures for improving weld metal tensile elongation were observed to be: (*a*) cold roll, weld, and age; and (*b*) age, weld, and further age. Flash annealing enhanced these treatments also.

Stress relieving or re-sclution treating between welding and aging resulted in less attractive aged tensile properties than simple weld and age procedures.

Some specific promising procedures, along with the ultimate tensile strength and elongation values obtained in longitudinal tension loading, were:

1. Cold roll 10%, weld, age 900° F, 4 hr, and flash anneal, gave 150 ksi, 13%.
2. The same treatment except that the 900° F age was extended to 8 hr gave 169 ksi 8%.
3. Age 900° F, 40 hr, weld, age 900° F, 2 hr and flash anneal gave 157 ksi, 8%.
4. Weld with magnetic stirring, age 900° F, 20 hr, and flash anneal gave 178 ksi, 4%.
5. Weld with magnetic stirring, age 900° F, 80 hr, flash anneal gave 208 ksi, 2%.

Acknowledgments

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Bibliography

1. Rudy, J. F., Crossley, F. A., and Schwartzhart, H., "Investigation of Heat Treatment and Welding Characteristics of B 120 VCA Titanium Alloy Sheet," Armour Research Foundation Report No. 2164-12 to Bureau of Weapons, Contract No. NOas 59-6054-c.

2. Rawe, R. A., Dupouy, J. M., and Bever, M. B., "The Aging Characteristics of the Ti-13V-11Cr-4Al Alloy," *Trans. AIME*, Vol. 218, Oct. 1960, p. 821.

3. Tanner, L. E., "The Isothermal Transformation of Ti-13V-11Cr-3Al," ASM 1960 Preprint No. 206, presented at Philadelphia Oct. 17–21, 1960.

4. Crossley, F. A., "Magnetic Stirring: A New Way to Refine Metal Structure," *Iron Age* Sept. 8, 1960, p. 102.

EUROPEAN WELDING RESEARCH

(Continued from page 446-s)

avoided.

• The percentage of current shunted past the welds in indirect spot welding was found to vary from 12–20% for electrodes spaced 8 in. apart to 30–50% for electrodes spaced 2 in. apart in mild steel sheet 0.039 to 0.078-in. thick.

Automatic Welding

The November 1960 issue of Russia's *Avtomaticheskaya Svarka* contains the following articles:

• To measure residual stress in the heat affected zone of hardenable steel the X-ray diffraction method was used. Since sharp X-ray lines could not be secured from the heat-affected zone, a thin layer of non-hardenable metal, mild steel, was deposited on the plate before the butt joint was made. The mild steel deposit overlaying the heat-affected zone did not harden when the plates were welded together. By means of this method the same pattern of tensile stress (25,000 psi) in the weld, compressive stress (40,000 psi) close to the weld, and tensile stress (70,000 psi) $^3/_4$ in. from the weld center line was measured as was obtained by the lengthy mechanical method of measuring residual stress.

• An electron microscope was used to examine weld fractures. Electron microfractographs of mild steel broken at low temperature reveal entirely different structures for tough and brittle fractures.

• Time-temperature charts are given

• *(Continued on page 480-s)*

Transition-Temperature Correlations in Constructional Alloy Steels

Correlation is found to exist between "low blow" transition temperature and the temperatures of crack arrest in wide-plate tensile tests and self-stressed specimens, and service failures

BY G. M. ORNER AND C. E. HARTBOWER

ABSTRACT. Previous work resulted in an easily executed variation of the standard technique for testing Charpy impact specimens which permits a separation of the crack initiation and crack propagation stages of the fracture process. The technique requires "initiation" of a crack by means of a low-energy blow and propagation of the crack by a full-capacity blow of the impact-machine pendulum. The transition temperature so obtained has been demonstrated to be independent of specimen size, notch geometry and other test variables; thus, it is considered to be a material property having practical engineering significance. The low-blow transition temperature is believed to be the maximum temperature at which an initiating crack can become self-propagating in a thick plate where the energy required to produce shear lips is small compared with the elastic energy available for crack propagation.

In this investigation correlation was sought between the "low-blow" transition temperature (LBTT) and the temperatures at which brittle fracture occurred in four service casualities. Comparisons were also made between the LBTT and the Naval Research Laboratory drop-weight nil-ductility transition (NDT) temperature, wide-plate crack-arrest temperature, and the maximum temperature at which brittle fracture would propagate in special "wide-plate" crack propagation tests. Low-blow transition-temperature tests were also made using large (1.2 sq in. cross section) Charpy specimens in two steels on which similar tests had been made using a variety of specimen sizes ranging from one-half to double standard size.

In the case of the service-casualty materials, the low-blow transition temperatures fell above the casualty temperature in all cases, and the LBTT and NDT correlated within 20° C. Comparison between LBTT and wide-plate crack-arrest temperatures indicated near one-to-one correlation. In the case of the special crack-propagation tests using self-stressed specimens, the maximum temperature at which brittle fracture would propagate was somewhat below the LBTT due, it is thought, to the low stresses involved in the tests. The LBTT determined from the over-size Charpy specimens confirmed the earlier observation, that the LBTT is independent of specimen size.

G. M. ORNER and C. E. HARTBOWER are with Manufacturing Laboratories, Inc., Cambridge, Mass., having been previously associated with the Watertown Arsenal Laboratories, Watertown, Mass. (The opinions or assertions contained herein are private ones of the authors and are not necessarily to be construed as official or reflecting the view of the Department of the Army.)

Paper presented at the AWS 42nd Annual Meeting held in New York, N. Y., during Apr. 17-21, 1961.

Introduction

The classical concept of brittle fracture in structural steels, from Mesnager and Ludwick, postulates that the small amount of plastic deformation, which occurs at the tip of an advancing cleavage crack, generates sufficient plastic constraint to raise the yield strength to the cohesive-strength level and, thus, maintains cleavage-crack propagation.[1, 2] Orowan and Felbeck,[3, 4] however, in brittle-fracture experiments on ship plates demonstrated that this concept required drastic revision, because it failed to take into account the highly important effect of strain rate. They observed as has been observed by many investigators since, that an arrested cleavage crack requires copious plastic-deformation work at its tip before it will reinitiate and propagate as cleavage. From this observation they deduced that the very small amount of plastic deformation associated with cleavage cracking was insufficient to supply the plastic constraint necessary to raise the yield stress to the cohesive-strength level at low rates of strain. However, once a crack was propagating as cleavage, the high strain rate associated with this type of cracking was sufficient to maintain cohesive-strength stress levels with little help from plastic constraint.

Since yield strength is dependent also on temperature, it follows from the above concepts that, for any one steel, there is a certain critical temperature at which the stress-raising effects of plastic constraint and strain rate at the tip of a propagating cleavage crack are just sufficient to maintain cleavage-strength stress levels and, hence, cleavage crack propagation. Above this temperature, a cleavage crack will be self-arresting; below this temperature a cleavage crack will be self-propagating. In other words, in a stressed plate a cleavage crack will be propagated by the elastic energy released as a result of crack extension. Since cleavage-crack initiation may occur as a result of high local stress at some seemingly insignificant mechanical or metallurgical discontinuity, this transition is highly significant in terms of service behavior. It is this transition that is believed to be indicated by the Charpy "low-blow" method of transition temperature determination.[5]

It has been demonstrated that the low-blow (precracked) Charpy transition temperature is independent of notch geometry and specimen size within the limits investigated, i.e., using specimens one-half-width standard-depth to double width standard-depth.[6, 7] The low-blow transition temperature, hereinafter referred to as LBTT, is believed to be the maximum tempera-

Table 1—Chemical Composition (% by Weight) and Tensile Properties of Service-casualty Materials

Case No.	C	Mn	Si	P	S	Mo	Ni	V	Cr	Yield strength, ksi	Tensile strength, ksi
2	0.17	0.40	0.05	0.026	0.031	...	...	...	...	52	78
5	0.19	0.90	0.27	0.010	0.021	0.52	...	...	...	...	...
8	0.28	0.70	0.19	0.015	0.010	0.48	2.64	0.07	...	96	116
12	0.30	0.85	0.22	0.010	0.010	1.18	0.17	0.20	0.78	142	157

ture at which catastrophic fracture can occur in structural-steel sections of sufficient thickness so that the energy absorbed by the shear lips is small compared with the elastic energy available for propagation of the crack. Data obtained by Robertson, using his "crack arrest" test have indicated that the minimum thickness complying with this provision is of the order of 1 in.[8]

In the low-blow test the Charpy notches are conditioned by prestraining. Thus, upon reloading the specimen at impact rates of strain at and below the transition temperature, cleavage cracking can be initiated without the necessity of appreciable additional plastic-deformation work. The resulting energy-temperature curves show an inflection* at a low-energy level, denoting the maximum temperature at which only elastic energy is required for propagation of the crack in the center portion of the specimen, i.e., the cracked area excluding the shear lips.

The objective of this investigation was to seek correlation† between the LBTT, service-failure temperatures and other significant fracture transitions. Low-blow Charpy tests were conducted on large ($6^3/_8$ x 1 x $1^3/_{16}$ in.) Charpy specimens to further demonstrate the size independence of the LBTT. Comparisons were made between the LBTT and results from wide-plate crack-arrest tests, Naval Research Laboratory (NRL) drop-weight (NDT) tests and special crack-propagation tests. LBTT determinations were also made on several service-casualty steels and the results compared with the temperature prevailing at the time of failure.

Materials

Service-casualty Steels

Materials were obtained through the courtesy of P. P. Puzak of the Naval Research Laboratory in the form of broken-drop-weight specimens. The chemical compositions and tensile properties in Table 1 were obtained from the NRL report.[9]

ABS Class-C Steel

The ABS Class-C material was supplied through the courtesy of Professor R. J. Mosborg of the University of Illinois in the form of a $^3/_4$-in. thick rolled plate in the normalized condition. The chemical composition and tensile properties in Table 4 were obtained from Professor Mosborg's report.[11]

Test Procedures and Results

Service-casualty Materials

The steels used in these tests represent four of seventeen service-casualty materials evaluated for NDT (by the drop-weight test) and

Table 2—Chemical Composition (% by Weight) and Hardness of "X" Steels

Heat No.	Carbon	Mn	Mo	Si	S	P	Cr	B	R_c
0140	0.29	1.80	0.47	0.18	0.017	0.018	...	...	39
0181	0.26	1.73	0.42	0.18	0.013	0.011	0.02	0.0002	39
0531	0.24	1.57	0.49	0.16	0.013	0.014	...	0.0002	37

Case 2 involved a $^5/_8$-in. thick semikilled ship plate; Case 5 a $1^3/_4$-in. thick A204 pressure-vessel steel, Case 8 a $7^5/_8$ in. thick A293 pressure vessel steel and Case 12 a 76-in. OD 12 x 13-in. square section of A293 Cr-Mo-V steel.

High-hardness "X" Steels

These materials were obtained in the form of $^5/_8$ in. thick plate under Army Specification MIL-A-12560 at a tensile strength of approximately 180 ksi. The chemical compositions in Table 2 were obtained from an NRL report.[10]

reported by the Naval Research Laboratory.[9] The case histories and other pertinent data on these materials have been taken directly from the NRL report. In each case the material for test was taken from the "source" plate, i.e., the plate or forging in which fracture initiated.

Low-blow transition temperature tests were run according to the procedures described in previous reports.[5-7] Since the NDT's of these steels were above room-temperature (with one exception), pre-

Table 3—Chemical Composition (% by Weight) and Tensile Properties (Ksi) of Class B and 90 Steels

Steel	C	Mn	Si	S	P	Ni	Cr	Mo	V	Cu	Yield strength	Tensile strength
Class B	0.195	1.13	0.04	0.025	0.017	...	...	...	...	0.017	48	79
Class 90	0.17	0.33	0.23	0.030	0.04	2.13	0.97	0.22	0.03	0.057	96	110

Class-B and Class-90 Steels

The Class-90 material was purchased under Ordnance Specification MIL-S-13326 (ORD) in the form of quenched-and-tempered 1-in. thick plate, and the Class-B steel was purchased under U. S. Army Specification No. 57-114-1 in the form of as-rolled 1-in. thick plate. Referring to Table 3, these are the same materials (same heats) as were used in previous LBTT studies.[7]

cracking was done at elevated temperatures to avoid the possibility of completely fracturing the specimens with the low-energy blow. Standard Charpy V-notches were used throughout these tests. Specimen depth was 0.394 in. (standard) in all cases, but specimen width was made, in so far as possible, approximately equal to the thickness of the broken drop-weight specimen from which

Table 4—Chemical Composition (% by Weight) and Tensile Properties (Ksi) of ABS Class-C Steel

Steel	C	Mn	P	S	Si	Cu	Cr	Ni	Al	Yield strength	Tensile strength
Class C	0.24	0.69	0.022	0.030	0.20	0.22	0.08	0.015	0.034	48	72

* Experience has shown that the low-blow transition data in the vicinity of the inflection can generally be represented by two straight lines. The temperature corresponding to their intersection is taken to represent LBTT.

† For reasons to be explained, a one-to-one correlation between LBTT and service-failure temperature was not expected.

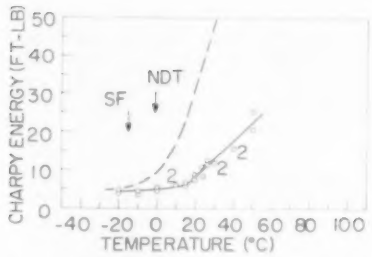

Fig. 1—Energy-temperature curves for Case 2 material. The plotted data represent energy-to-propagate vs. testing temperature for 0.592 x 0.394-in. Charpy specimens. The NDT and the dashed line, the latter representing conventional (single-blow 0.394-in. sq) V-notch Charpy data, are from the Naval Research Laboratory.[9] Note that the service failure occurred at −15° C, the NDT at approximately 0° C and the LBTT at +15° C

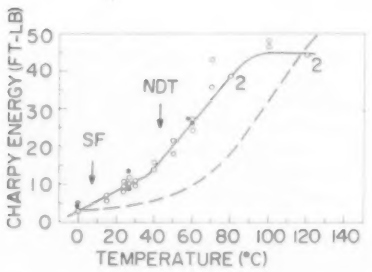

Fig. 2—Energy-temperature curves for Case 5 material. The open circles represent energy-to-propagate plotted against temperature for 0.685 x 0.394-in. Charpy specimens. The NDT and the dashed line, the latter representing conventional V-notch Charpy data, are from the Naval Research Laboratory.[9] Note that the service failure occurred at 7° C, the NDT at approximately 43° C and the LBTT at 37° C. The closed circles represent conventional data obtained at the Watertown Arsenal Laboratories from 0.394-in. sq specimens; note that these data do not check the NRL (dashed) curve

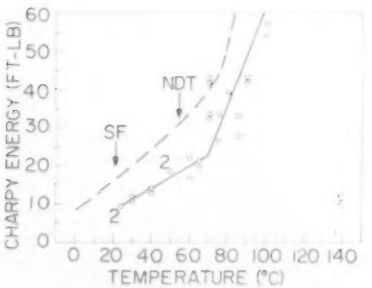

Fig. 3—Energy-temperature curves for case 8 material. The plotted data represent energy-to-propagate vs. testing temperature for 0.627 x 0.394-in. Charpy specimens. The NDT and the dashed line, the latter representing conventional V-notch Charpy data, are from the Naval Research Laboratory.[9] Note that the service failure occurred at 22° C, the NDT at 54° C, and the LBTT at 70° C

the Charpys were cut. The object of using wider-than-standard specimens was threefold: 1. Wider specimens tend to give more sharply defined inflections in the energy-temperature curves than narrower specimens. 2. It is more economical in machine-shop time to make specimens of full-plate thickness. 3. If metallurgical differences occur in the thickness direction, full-thickness specimens are more representative of the plate than thinner specimens. Otherwise, the width of specimen is arbitrary because only the temperature at which the inflection occurs in the energy-temperature curve is significant; energy values, *per se*, have little meaning.

The material from *Case Number 2* represents a typical World War II semikilled ship-plate type of steel. It was removed from the main deck of the *USS Markab;* the fracture, originating at the corner of a square-vent opening, occurred while the ship was moored to a buoy in Narragansett Bay in February 1954. The air temperature at the time of fracture was 5° F (−15° C). The Charpy energy-to-propagate temperature data are plotted in Fig. 1. Note that the LBTT is indicated to be +15° C., i.e., approximately 15° C higher than NDT and 30° C higher than the temperature at which the service failure occurred. The dashed curve represents conventional (standard 0.394-in. sq single-blow) Charpy data from the NRL report.[9]

Brittle fracture in *Case Number 5* occurred in a 7 ft diameter pressure vessel during hydrotest, fabricated from 1¾ in. thick A204 Grade-B steel. The temperature of the water used for test was 45° F (7° C). The Charpy energy-to-propagate temperature data for the source-plate material are plotted in Fig. 2. Note that the LBTT is indicated at 37° C, i.e., 30° C *above* the temperature at which the service failure occurred but 6 deg below the NDT. Since the LBTT is considered to be the highest temperature at which brittle fracture can propagate, an LBTT *below* the NDT was unexpected. As a check on the base material, six standard (0.394-in. sq) V-notch Charpy specimens were prepared from a second drop-weight specimen

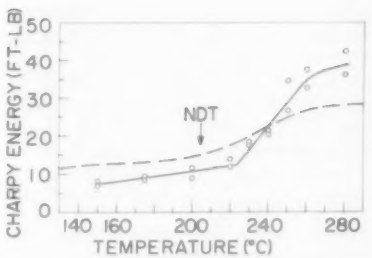

Fig. 4—Energy-temperature curves for case 12 material. The plotted data represent energy-to-propagate vs. testing temperature for .474-in. x 0.394-in. Charpy specimens. The NDT and the dashed line, the latter representing conventional V-notch Charpy data, are from the Naval Research Laboratory.[9] The service failure occurred at 22° C; note that the NDT occurred at 203° C and the LBTT at 225° C

and tested in the conventional manner. Note that these data (the closed circles in Fig. 2) do not check with the NRL data (the dashed curve). It is assumed that considerable inhomogeneity must have existed in this material and that the broken drop-weight specimen from which the LBTT Charpy specimens were cut was not representative of the other specimens used in determining the NDT.

Brittle fracture in *Case Number 8*, originating from a fatigue crack, occurred in a 7⅝ in. thick A293 Ni-Mo-V pressure-vessel forging during service involving cyclic-type loading. The service failure occurred at room temperature. The Charpy energy-to-propagate data plotted in Fig. 3 show a LBTT of 70° C, i.e., 15° C above the NDT and approximately 45° C above the service-failure temperature. Although there is scatter in the Charpy results at temperatures above the inflection point, the inflection itself is well defined.

The material from *Case Number 12*, an A293 Cr-Mo-V steel, was taken from a heavy forged retaining ring for an aluminum-extrusion container. Failure occurred at room temperature, initiating spontaneously from microcracks in the vicinity of a thermocouple that had been silver brazed to the retaining ring. The extrusion press was not

Table 5—Failure and Transition Temperatures (° C) for Service-casualty Materials

Case No.	Low-blow Ft-lb	Low-blow Temp	Specimen width (in.)	Service failure	NDT	LBTT
2	30	+100	0.592	−15	0	15
5	32	+100	0.685	7	43	37
8	50	+100	0.627	22	54	70
12	25	+250	0.747	22	204	225

in use at the time of failure; however, the retaining ring was a shrink fit on the container and therefore highly stressed. The LBTT occurred at 225° C (Fig. 4), i.e., 20 deg above the NDT and about 200 deg above the service-failure temperature.

Note, from Table 5, that in all cases investigated the LBTT was higher (30° C or more) than the service-failure temperature. Furthermore, correlation within 20° C is indicated between NDT and LBTT, with the LBTT temperature being the higher (except for the anomalous result in Case No. 5 material). Basically, both the drop weight and the low-blow tests are conducted by initiating cleavage fracture in specimens stressed at various temperatures, transition being taken as the highest te.nperature at which brittle fracture is propagated by the elastic energy contained in the specimen. This temperature is determined in the low-blow Charpy test by the inflection in the energy-to-propagate temperature curve, and in the drop-weight test by direct observation. Thus, a correlation between LBTT and NDT is to be expected. However, it has been observed by several investigators,[12] that unless drop-weight specimens are heat treated *after* welding,* the crack-starting weld beads may produce tough elements in the heat-affected zone with lower transition temperature than the base material. The tough elements may arrest the cleavage crack and thereby depress the NDT to anomalously low values.

It is generally felt that the only way to prove the validity of a transition-temperature test is to show that it correlates with service failures. However, because low temperature is a necessary but not a sufficient condition for the initiation of a brittle fracture, service failures usually occur at a temperature considerably below the highest temperature at which brittle fracture may be propagated by continuous release of the elastic-stress field surrounding the crack. Thus, the only "correlation" that can be hoped for, is to show that each failure investigated occurred below the indicated transition temperature.

High-hardness "X" Materials

Coupons from three of the "X" materials investigated by drop-weight and conventional Charpy tests at the Naval Research Laboratory were obtained and tested by low-blow Charpy. These materials represent identical heats, but not identical plates to those used in the NRL investigation.[10]

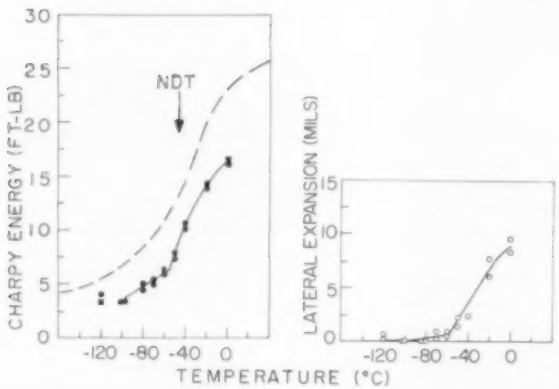

Fig. 5—Energy and lateral-expansion vs. temperature for high hardness "X" material, heat 0181. The open and closed circles represent the lateral expansion (O) and energy (●) associated with crack propagation, respectively. The NDT and the dashed line, the latter representing conventional V-notch Charpy data, are from the Naval Research Laboratory[10]

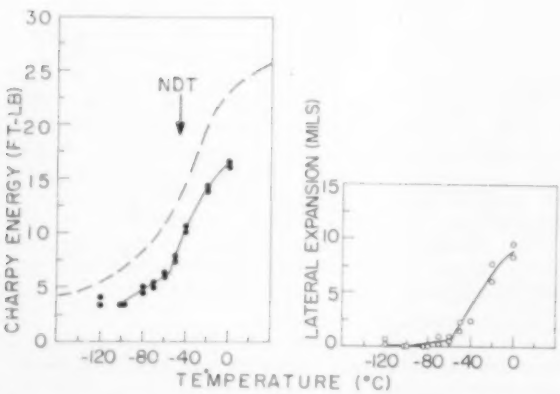

Fig. 6—Energy and lateral-expansion vs. temperature for high hardness "X" material, heat 0531. The open and closed circles represent the lateral expansion (O) and energy (●) associated with crack propagation, respectively. The NDT and the dashed line, the latter representing conventional V-notch Charpy data, are from the Naval Research Laboratory[10]

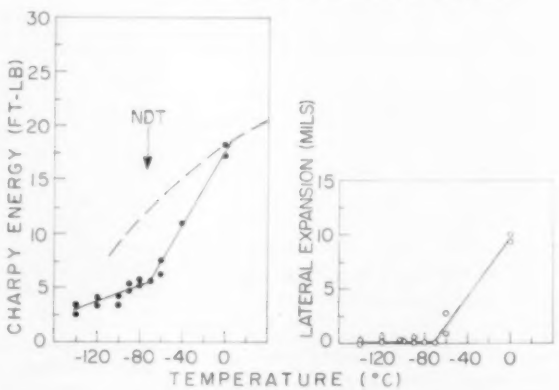

Fig. 7—Energy and lateral-expansion vs. temperature for high hardness "X" material, heat 0140. The open and closed circles represent the lateral expansion (O) and energy (●) associated with crack propagation, respectively. The NDT and the dashed line, the latter representing conventional V-notch Charpy data, are from the Naval Research Laboratory[10]

* Investigators at Westinghouse Electric Corp. Bettis Atomic Power Div. have evaluated several steels using both the LBTT and NDT tests. The drop-weight specimens were rehardened and tempered *after* welding the crack-starter pads (Stellite No. 1) to eliminate the weld heat-affected zone. Charpy specimens were cut from the broken drop-weight specimens. The materials tested included AM-355 (consutrode), Type 410-SS, AISI-4145 (modified) and AISI-4340, ranging in hardness from 20 to 40 Rc. The LBTT's ranged from +170 to −115° F. The differences between LBTT and NDT temperatures ranged from 5 to 40° F, with an average difference of 14° F in the 16 steels investigated. The arithmetic mean (i.e., the algebraic sum divided by the number of materials tested) was less than 1 deg, indicating that the same transition temperature was determined by both tests.

The actual plotted curves, together with NRL drop-weight NDT and Charpy data are presented in Figs. 5 through 7. In Fig. 7, the fact that the energy-to-propagate data at 0° C superimposes on the conventional Charpy data is believed to indicate that the specimen orientation with respect to rolling direction was longitudinal in the low-blow (WAL) tests and transverse in the conventional (NRL) tests (earlier low-blow studies indicated very little difference in *LBTT* with respect to rolling direction in steel).

Table 6—NDT and LBTT (° C) for Three High-hardness "X" Materials

Heat No.	NDT	LBTT
0181	−60	−50
0140	−75	−70
0531	−50	−55

The results from the high-hardness "X" materials are tabulated in Table 6. Note that correlation between LBTT and NDT is shown in all three cases, within the limits of experimental error and plate-to-plate variations within a single heat.

It is interesting to note that two of the three heats of steel have been investigated at Rensselaer Polytechnic Institute[13] using the RPI synthetic-specimen technique to determine the effects of weld thermal cycles on the notch toughness of those regions of the weld heat-affected zone heated to peak temperatures within the critical range. When tough HAZ's are produced in a material, fictitiously low NDTs may be expected. In these particular "X" materials, the LBTT and NDT temperatures were nearly the same, apparently because the HAZ's are more brittle than the base metal. The RPI data based on a 10 ft-lb energy criterion appear in Table 7.

Table 7—Synthetic-HAZ Transition Temperatures, ° C[a]

(10 Ft-lb Energy Criterion)

Base metal		HAZ peak temp., ° C					
Heat	As-rec'd	871	843	816	788	760	732
0531	−45	30	30	30	20	50	115
0181	−70	−20	−40	−50	−15	30	110

[a] Energy input 47,000 Joules/in.

Fig. 8—Large specimen compared with standard 0.394 x 0.394-in. V-notch Charpy specimen

It is interesting to note that when the material was exposed to a double thermal cycle, i.e. a 732° C (1350° F) peak temperature followed by a 538° C (1000° F) peak temperature, the toughness of the HAZ was completely restored—in fact, the HAZ was now decidedly tougher than the unwelded base metal with a 10 ft-lb transition temperature of −145° C. Thus, if a two-pass crack-starter bead were deposited for some reason, or if a stress-relief treatment were used after depositing the crack-starter bead, fictitiously low NDT temperatures could be expected. The fact that the lowest peak temperature investigated by RPI coincided with the lower critical (A_c) and yet produced extreme embrittlement is interesting in that one would normally associate such a temperature with maximum tempering effects.

Large Charpy Tests

Charpy low-blow transition-temperature tests in three steels, using Charpy V-notch specimens ranging from half-to-double width and half-to-full depth, have demonstrated that the LBTT is independent of specimen size within the limits of the sizes tested. To extend the size of test specimen, V-notch Charpy specimens measuring approximately $6^3/_8$ x 1 x $1^3/_{16}$ in. (Fig. 8) were prepared from two of the previously tested steels and tested in a 2200 ft-lb

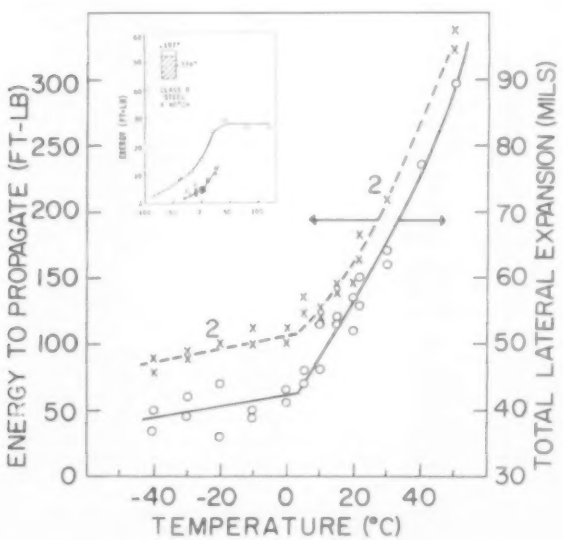

Fig. 9—Energy and total lateral-expansion vs. temperature curves for large-size Charpy specimens in Class B steel. Note that the LBTT occurred at +5 deg as determined by both criteria. Prior tests using standard and subsize Charpy bars indicated the LBTT at 0° C

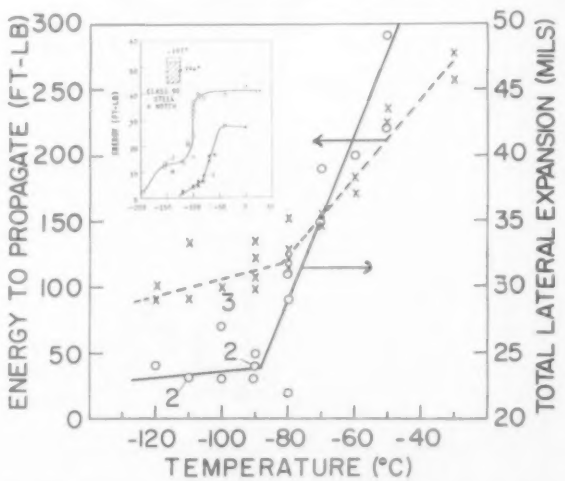

Fig. 10—Energy and total lateral-expansion vs. temperature curves for large size Charpy specimens in class 90 steel. Note that the LBTT occurred at approximately −85° C as determined by both criteria. Prior tests using standard and subsize Charpy bars indicated the LBTT at −80° C

capacity Charpy impact machine. The magnitude of the low-energy blow necessary to produce cracking in these large specimens proved to be quite critical, more so than with the smaller sizes of specimens. In the preliminary tests, cleavage cracking was sometimes initiated in the Class-B specimens when impacted with the low-energy blow at room temperature, resulting in the formation of too-deep a crack. The temperature at which the low-blow was struck on the remaining Class-B specimens was therefore raised to +60° C.

The energy-temperature curves obtained from these tests are presented in Figs. 9 and 10. Transitions are indicated at about 0 and −85° C for the Class-B and Class-90 materials, respectively, which correlates well with the transitions obtained using smaller specimens (0 and −80° C respectively).

Correlation of LBTT with Crack-arrest Tests

A "crack-arrest" study was made at the University of Illinois[11] for the Ship Structure Committee, under U. S. Navy Bureau of Ships Contract Nobs 65789. The object of these tests was to investigate the possibility of halting a brittle fracture with a strake of notch-tough steel welded between strakes of standard structural (rimmed) steel. Of the two steels investigated, one was a fully-killed normalized ABS Class-C steel. The arresting ability of this steel in widths of 6, 18 and 60 in. was investigated in the presence of a propagating 1-ft long crack with an average stress of 20 to 33 ksi. Testing temperatures in the University of Illinois tests ranged from −25 to +40° F. A transition in behavior from complete fracture to complete arrest occurred between +10 and +35° F. The fracture-arrest temperature was compared with conventional Charpy criteria and found to correspond to 45 to 65 ft-lb on the energy-temperature curves, 45 to 60 mils on the lateral expansion-temperature curves and 45 and 65% fibrosity on the crystallinity-temperature curves (Fig. 11). Furthermore, when drop-weight tests were conducted on the C-steel plates used in the University of Illinois investigation, NDT's of −20 to −30° F were obtained. This corresponded to a V-notch Charpy impact energy level of 30 to 35 ft-lb which, incidentally, does not agree with the suggestion of Puzak and Pellini[10] that the temperature corresponding to 20 ft-lb gives a conservative value of NDT.

A sample of the 3/4-in. thick ABS Class-C steel, cut from the center of a 60-in. wide C-steel strake used in University of Illinois "test 31" was supplied to Watertown Arsenal Laboratories. V-notch Charpy impact specimens 0.727-in. wide by 0.394-in. deep were machined from the sample. Low-energy blows of 65 ft-lb were delivered to each specimen at room temperature to initiate cracking; the specimens were then fractured with a full blow of the pendulum. The energies absorbed from the full-capacity blows were recorded and plotted as energy-to-propagate versus testing temperature. The low-blow transition temperature, i.e., the temperature at the inflection in the transition curve (Fig. 11) occurred at approximately +25° F. In the University of Illinois crack-arrest tests, on the same plate, the transition from complete fracture to complete arrest occurred between +10 and +35° F; thus, good agreement between the LBTT and the wide-plate crack-arrest temperature was indicated.

In Scotland, Colvilles Ltd.[14] has conducted wide-plate tests similar to those conducted at the Univer-

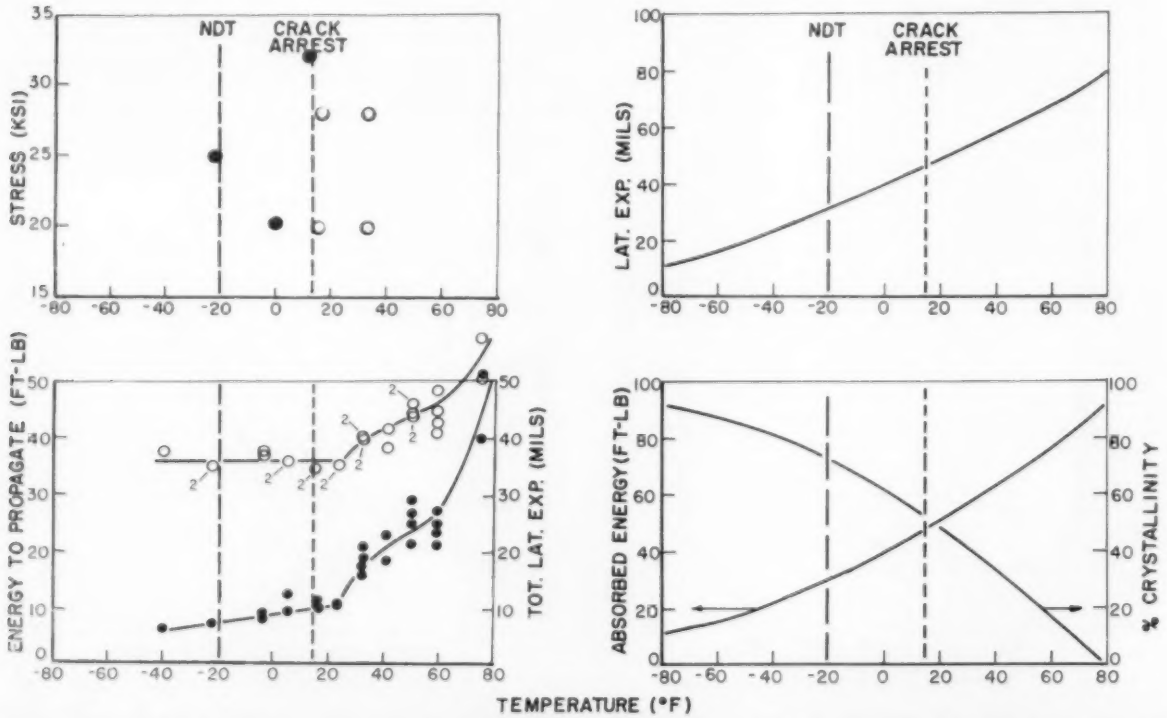

Fig. 11—University of Illinois crack-arrest studies and LBTT results on ABS Class C Plate. The lower left-hand plot was obtained by means of the Charpy low-blow technique (open circles represent total lateral-expansion). The right-hand curves were obtained from conventional (single-blow) V-notch Charpy impact tests. The upper-left-hand plot presents the wide-plate test data, where the open circles represent crack arrest and the closed circles, crack propagation in the Class-C strake (Plate No. 12-1)

sity of Illinois. The material tested was 1-in. thick Coltuf "28" (Test No. 9930J ex Cast No. H5373) with a mean Robertson crack-arrest temperature of −47° C. Isothermal wide-plate tests were prepared consisting of an 18-in. strake of mild steel butt welded to 18-in. of Coltuf 28. At −30, −20 and −15° C, the crack propagated in the Coltuf 28; whereas, at −10° C the crack was arrested completely. Thus, the crack-arrest temperature in the isothermal tests was appreciably higher than that predicted by the Robertson temperature-gradient crack-arrest test.*

At −15° C, the lowest temperature for complete crack arrest in the wide-plate crack-arrester tests, the conventional V-notch Charpy impact energy was 40 ft-lb and the fracture 95% fibrous (fracture parallel to the rolling direction).

Colvilles Ltd. then carried out low-blow tests on the Coltuf 28, used in their wide-plate tests, to check for correlation between the low-blow transition and the temperature for complete crack arrest. A positive inflection in the energy-temperature curve occurred at −15° C, thus, providing a one-to-one correlation with the wide-plate crack-arrest tests.[14]

Crack-propagation Test

Numerous investigations on brittle fracture have been conducted using large-plate specimens. The specimens are usually stressed in conventional tensile machines adapted for the purpose; in some cases, special machines have been built. The plates are cooled to the desired test temperatures and brittle fractures initiated from a notch at one end. The material surrounding the notch is precooled and locally stressed, usually by impacting some type of wedging device. The tensile fixtures necessary for these tests are quite massive and expensive to make, and temperature control is difficult. Furthermore, although axial loading of the test plate before fracture starts is relatively simple, maintaining axial loading during crack propagation is almost impossible with conventional loading fixtures. Robertson[3] has pointed out that, because of the high velocity of the crack, fracture is completed before appreciable nonaxial loading occurs, if the distance from the propagating crack to the grips is sufficiently great. However, he has also shown that, if a relatively high stress is used in isothermal tests at temperatures slightly above the crack-arrest temperature, an arrested brittle crack may reinitiate after considerable plastic deformation has occurred at the tip of the crack. This plastic deformation is a result of increased local stresses due to nonaxial loading and the over-all increase in stress due to the reduction of the cross-section area left to support the load. Actually, the stress condition in the remaining section of a testpiece during crack propagation is very difficult to assess, because it is dependent on many factors, including the speed of the crack and the resulting inertial effects, the geometry of the testpiece and loading fixtures, and the softness (i.e., lack of rigidity) of the test machine and connecting devices. To overcome most of these difficulties the specimen illustrated in Fig. 12 was devised, and a number of specimens were made and tested.

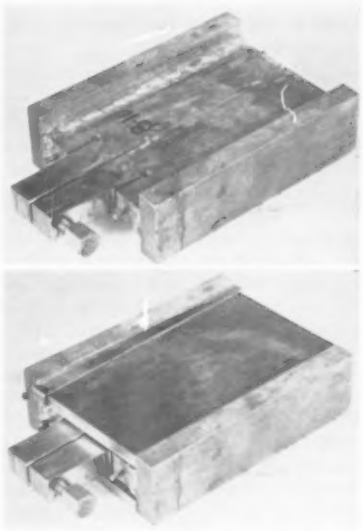

Fig. 12—Crack-propagation specimen. The lower view shows the loaded specimen, i.e., with the wedge plates in position. The upper view shows a Class-B steel specimen after crack propagation at −15° C; lateral contraction is visible in the plate surface indicating the path of crack propagation beneath the surface

The specimen consists of a $5^1/_2$ by $9^1/_2$ by 1-in. test plate with 1-in. thick flanges welded along the $9^1/_2$ in. edges to form an "I" section. The inner surfaces of the flanges were machined and ground parallel to each other. Two pairs of wedge plates were prepared, each pair consisting of a narrow and a wide tapered plate with edges machined and ground. In that the wedges were made with identical tapers, the outer edges of each assembled pair were parallel. (The lower view of Fig. 12 shows the wedges assembled with a test plate.) Wedge plates were cooled in liquid nitrogen and then inserted on either side of the test plate, the narrow wedges being driven home with a light hammer. When the entire test assembly attained a uniform temperature, the thermal expansion of the wedge plates stressed the test plate to approximately 20 ksi (computed by measuring the elastic strain between pairs of hardened steel pins fixed to either end of the test plate).

Although the specimens are somewhat expensive to prepare, they have the following obvious advantages:

1. No special testing fixture or machine is required.
2. Axiality of loading (uniform stress in the remaining section) is assured during all stages of crack propagation.
3. Temperature control is easily obtained since the entire test assembly, except for the notched area, is entirely submerged in a liquid bath.
4. The energy for the propagation of the crack comes entirely from the elastic energy stored in the specimen and wedge plates.

Specimens tested in the vicinity of 0° C were cooled with dry ice in an alcohol bath, the dry ice being added directly to the bath. Bimetallic thermometers were used to measure temperature. Specimens tested in the vicinity of −80° C were cooled in an isopentane bath. A double container was used, liquid nitrogen being poured into the outer container as required to maintain the desired temperature level. Agitation of the alcohol bath occurred naturally from the sublimating dry ice. The isopentane bath was stirred mechanically, and temperatures were measured with an iron-constantan thermocouple and direct-reading potentiometer. Specimens were held in the cooling bath at temperature for at least 30 min before each test. Local cooling of the notched areas was accomplished by pouring liquid nitrogen into semicircular steel cups clamped on either side of the lugs containing the notch. When violent boiling of the liquid nitrogen ceased (after 4 or 5 min), the set screw was tightened to spread the lugs and initiate cleavage cracking.

* IIW Subcommission A, in Document IX-A-12-58, comparing Robertson gradient tests and isothermal crack-arrest tests, reported, "Although no extensive testing was done, under some circumstances at the same stress a crack can run right through the (isothermal) specimen at a temperature 20° C above the arrest temperature determined from gradient tests."

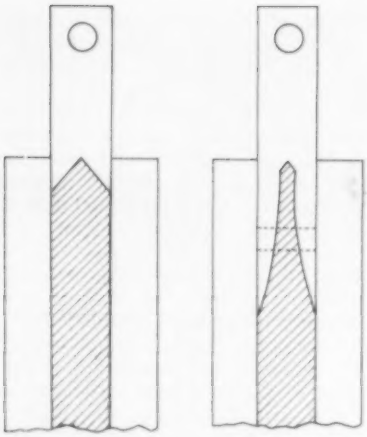

Fig. 13—Crack - propagation - specimen notch geometries. The geometry illustrated at the left was unsatisfactory and was modified to the geometry shown on the right. (Dotted area at right indicates $^3/_8$-in. drilled hole at end of saw cut—Fig. 12)

Table 8—Wide Plate Test Results

Material	Stress, ksi	Test temp., °C	Results of test
Class B	20	+10	Crack arrested after propagating approximately 1 in. into main body of specimen
Class B	22	0	Crack arrested after propagating approximately 1 in. into main body of specimen
Class B	23	−15	Crack ran internally for full length of specimen. Shear-lips were not fractured
Class 90	20	−90	Crack arrested after propagating approximately $^3/_4$ in. into main body of specimen
Class 90	13	−100	Crack arrested after propagating approximately 2 in. into main body of specimen
Class 90	19	−120	Complete fracture of specimen, including shear-lip areas

The first notch geometry tried is illustrated on the left in Fig. 13. It was thought necessary to have the notch tip within the area stressed by the wedge plates to insure that the crack would not have to run through an unstressed area before entering and main body of the specimen. However, an attempt to initiate cracking with this type of notch failed, even though the lugs were severely deformed. To facilitate crack initiation, the notches were modified to the geometry illustrated on the right in Fig. 13. Because of the greatly reduced thickness of the plate in the notched area, it was thought that the stress resulting from the tightening of the set screw would be sufficient to drive the crack into the main body of the specimen where the stress from the wedge plate would take over. With this geometry, cleavage cracking was easily initiated. However, in one test, cracking was arrested in the notched area, presumably due to insufficient stress.

The results from the tests are presented in Table 8. The Class-B material is a coarse-grained pearlitic material in the as-rolled condition which had shown some scatter in LBTT tests; the LBTT varied between −10 and +5° C in a series of tests involving different specimen sizes. In the special test, the crack ran the full length of the specimen at −15° C but was arrested at 0 and +10° C. It is interesting to note that, in the case of the specimen tested at −15° C where the crack ran the full length of the test plate, *complete* fracture did not occur. The crack propagated internally only; the shear lip areas, although plastically deformed, were not broken. The upper view of Fig. 12 (wedge-plates removed) shows this specimen after testing, before the two halves were separated. The crack path, running the full length of the specimen appeared as a narrow depression on the Blanchard ground surface of the plate. Figure 14 illustrates the fracture surfaces of the same specimen after separation at room temperature.

Figure 15 shows a typical arrested crack in the Class-B steel, tested at +10° C. The cracked section of the specimen was heated to a blue heat with a gas flame to discolor the cracked surfaces and then broken apart at −196° C by tightening the set-screw. The dark band running across the fracture surface at an angle is the dark-purple temper color. Below this band a straw color was evident, presumably because the crack was so narrow that insufficient oxygen was available to produce a deeper color.

In the case of the Class-90 steel, a quenched-and-tempered low-alloy material with a LBTT of −80 to −90° C, the crack ran completely through the plate (including the shear-lip areas) at −120° C, ran about half way through the plate at −100° C, and was arrested immediately outside the notched section at −90° C.

The results of these tests correlate quite well with the LBTT. However, the LBTT appears somewhat conservative, particularly in the case of the Class-90 material. It should be recalled that the LBTT provides the maximum temperature at which catastrophic fracture can occur in a thick cross section loaded to the yield stress. The stress used in these tests was approximately 20 ksi as compared with yield strengths of approximately 40 and 80 ksi for the Class-B and Class-90 materials respectively. Note that the difference between the LBTT and the maximum temperature at which the crack would propagate in these special tests was greater for the higher strength Class-90 material than for the lower strength Class-B material, presumably because the difference between the stress used for the tests and the respective yield strengths of the material tested was much greater for the Class-90 material.

Furthermore, at temperatures

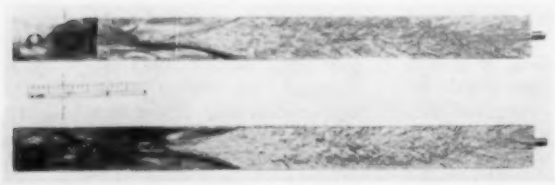

Fig. 14—Class-B crack-propagation-specimen fracture surfaces tested at −15° C, after separation at −196° C

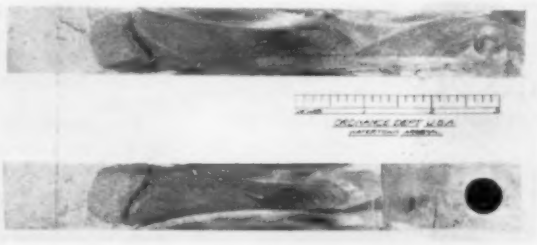

Fig. 15—Class-B crack-propagation-specimen fracture surfaces tested at +10° C, discolored by heating before separation at −196° C

very close to the transition, particularly when the stress values are low, a running cleavage crack is easily arrested. For instance, reflected compressive shock waves resulting from the sudden release of tension during the initial stages of crack propagation might conceivably counteract, momentarily, the tension stresses at the tip of the crack and arrest it. Unless there was sufficient stress to cause severe deformation at the tip of the crack, such an arrested crack could not reinitiate.

Summary Discussion

The low-blow transition temperature was shown to "correlate" with (i.e., fall above) the temperatures at which four service failures occurred. Furthermore, in these materials, the low-blow transition and the Naval Research Laboratory drop-weight nil-ductility transition (NDT) temperatures were shown to correlate within 20° C. In the case of the high-hardness "X" materials, the low-blow transition and the NDT correlated within 10° C.

The low-blow transition temperature is indicated to be independent of specimen size over the wide range of specimen sizes that have been tested; the same low-blow transition temperature was observed in specimens whose cross-sectional areas varied from 0.078 to 1.2 sq. in.

In special crack-propagation tests, the method used for stressing the specimens was designed to insure uniaxial loading and constant stress in the uncracked portion of the specimens regardless of crack length. The maximum temperature at which crack propagation occurred was observed to be somewhat below the low-blow transition temperatures due, presumably, to the comparatively low stress in the special tests as compared with yield-strength stresses, prevailing in the Charpy tests.

Excellent correlation was observed between the low-blow transition temperature and the wide-plate crack-arrest test results obtained at the University of Illinois and at Colvilles Ltd. in Scotland. Although initially the stresses were quite low in the wide-plate tests, the running cleavage cracks entering the test strakes were 12 and 18 in. long. Thus from the Griffith concept and as a result of the reduction in cross-sectional area left to support the load and the nonaxial loading condition produced as the crack propagated, the stresses in the vicinity of the crack front were very high (probably near yield-point magnitude). The danger in using arbitrary Charpy energy values to determine transition temperature is well illustrated in these materials where the conventional V-notch Charpy energy values corresponding to the crack-arrest temperature in the wide-plate tests were in the range of 40 to 65 ft-lb.

The low-blow transition temperature (LBTT) marks the upper limit of temperature wherein catastrophic failure can occur under adverse service conditions. Below this temperature, all that is required for the catastrophic failure of a stressed structure is the initiation of a cleavage crack. However, many structures are operating satisfactorily at temperatures well below their transition temperature (LBTT) because the critical conditions necessary for the initiation of a cleavage crack have not occurred. Nevertheless, such structures are subject to brittle failure when and if conditions become favorable for the initiation of a cleavage crack. The lower the temperature the easier it is for a cleavage crack to initiate at an inadvertent notch or defect; thus, most service failures tend to occur at temperatures well below the maximum temperature at which cleavage crack propagation is possible. Therefore, in this investigation, a one-to-one correlation between service-failure temperature and the low-blow transition temperature was not expected. It was expected only that the low-blow transition temperature would fall above the service-failure temperature. Nevertheless, in the opinion of the authors, the low-blow transition temperature is not an unduly conservative transition temperature in that it represents the highest temperature at which brittle failure *can* occur under adverse service conditions.

References

1. Mesnager, A., Internat. Assn. for Testing Materials, Brussels Congress 1906, Rapport non-offic. No. A 6f, pp. 1–16.

2. Ludwick, P., and Scheu, R., *Stahl u. Eisen*, **43**, 999 (1923).

3. Orowan, E., "Energy Criteria of Fracture," THE WELDING JOURNAL, **34** (3), Research Suppl., 157-s (March 1955).

4. Felbeck, D. K., and Orowan, E., "Experiments on Brittle Fracture of Steel Plates," *Ibid.*, **34** (11), Research Suppl., 570-s (1955).

5. Orner, G. M., and Hartbower, C. E., "The Low-Blow Transition Temperature," Watertown Arsenal Laboratories Report No. WAL TR 112/87-7; also *ASTM Proceedings*, **58**, 623 (1958).

6. Orner, G. M., and Hartbower, C. E., "The Effect of Notch and Specimen Geometry on Charpy Low-Blow Transition Temperature," Watertown Arsenal Laboratories Report No. WAL TR 112/87-4; also THE WELDING JOURNAL, **36** (12), Research Suppl., 521-s (1957).

7. Orner, G. M., "Effect of Specimen Geometry on Charpy Low-Blow Transition Temperature," Watertown Arsenal Laboratories Report No. WAL TR 112/87-6; also *Ibid.*, Research Suppl., **38** (8), 315-s (1959).

8. Robertson, T. S., "Propagation of Brittle Fracture in Steel," *Jnl., Iron Steel Inst.*, **175**, 361 (December 1953).

9. Puzak, P. P., Babeki, A. J., and Pellini, W. S., "Correlations of Brittle-Fracture Service Failures With Laboratory Notch-Ductility Tests," THE WELDING JOURNAL, **37** (9), Research Suppl., 391-s (1958); also IIW Document IX-233-50.

10. Puzak, P. P., and Pellini, W. S., "Evaluation of the Significance of Charpy Tests for Quenched-and-Tempered Steels," *Ibid.*, **35** (6), Research Suppl., 275-s (1956).

11. Mosborg, R. J., "An Investigation of Welded Crack Arresters," *Ibid.*, **39** (1), Research Suppl., 40-s (1960).

12. Murphy, W. J., McMullen, W. D., and Stout, R. D., "Notch Toughness Tests," *Ibid.*, **36** (6) Research Suppl., 307-s (1957) and Discussion by Pellini, W. S., and Puzak, P. P., *Ibid.*, **36** (11), 511-s (1957); Gross, J. H., "Comparison of Charpy V-Notch and Drop-Weight Tests for Structural Steel," *Ibid.*, **39** (2), 59-2 (1960) and Discussion by Puzak, P. P., *Ibid.*, 66-s; and Agnew, S. A., Mittelman, M. D., and Stout, R. D., "Some Observations on the Kinzel and Drop-Weight Tests," *Ibid.*, **39** (5), 205-s (1960).

13. Nippes, E. F., Savage, W. F., and Paez, J. M., "Impact Characteristics of Heat-Affected Zones in Mn-Mo Armor Steels," *Ibid.*, **39** (1), Research Suppl., 31-s (1960).

14. Gilmour, R., "Investigation of the 'Low-Blow' Transition Temperature for Coltuf 'Z8' Used in Wide-Plate Tests," Colvilles Ltd. Metallurgical Report D.31/7 dated June 21, 1960.

Residual Stresses in Welded Plates

Magnitude and pattern of residual-stress distribution are presented for a wide range of plate and weld sizes

BY N. R. NAGARAJA RAO AND LAMBERT TALL

ABSTRACT. A summary is presented of an experimental investigation of the residual stresses produced in plates due to welding.

The plates are welded at either the centerline or the edge and the magnitude and pattern of residual stress distribution are presented for a wide range of plate and weld sizes. These distributions are useful in the prediction of residual stress distributions for shapes built up from the plates by welding. A knowledge of the residual stress distribution in a structural shape leads to the prediction of its column strength.

Introduction

A research project on the "Influence of Residual Stress on Column Strength and the Mechanical Properties of Rolled Shapes" has been in progress at Lehigh University under the guidance of Task Group 1 of the Column Research Council. This Task Group was assigned the task of determining the relationship between material properties and the strength of columns.[1]

Currently the project has been extended to the study of the strength of welded built-up columns. The investigation was concerned only with bars and universal mill plates of ASTM Designation A7 Structural Steel.

Purpose and Scope

Residual stresses are the stresses that remain in a material as a result of plastic deformations. These are caused by the uneven cooling of the material after hot-rolling as well as by various fabrication methods such as welding and cold bending.[2]

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Built up column sections which are formed by welding plates together have high compressive residual stresses that may reduce the column buckling strength considerably. As with all structural steel shapes, column strength is defined principally by the magnitude and distribution of residual stress.[3] The reduction in column strength is due to the presence of high compressive residual stress at certain critical sections of the shape, which lower the effective compressive yield stress at that point. For this reason the magnitude and distribution of residual stresses due to welding on the component parts of the built-up shape is important. A typical distribution of residual stress in a welded built-up H-section is shown in Fig. 1.

Although tests of H-shaped welded members exhibit a strength that is considerably less than that of corresponding rolled H-shapes, it would be expected that welded "box" columns would be somewhat stronger than the corresponding rolled members because of the presence of tensile residual stresses at the corners.[3] Theoretical investigations have shown this to be so, and experimental verifications are under way.

An experimental study was carried out to define the effect of welding on plates which could be used to form welded built-up shapes.

Influencing Factors

Residual stresses in welded plates are influenced by the geometry of the plates, the type of welding and the heat of welding, the speed of welding and the rate of cooling, with the geometry being the main factor.[2-4]

The molten weld metal deposited in the joints melts the adjacent base metal, the welded plate then cooling down to atmospheric temperature. The temperature gradient across the weld is steep but continuous. The theoretical analysis of thermal and residual stresses is made complex by the fact that the physical properites of the metal vary with temperature and also because plastic deformation is involved.[2, 5]

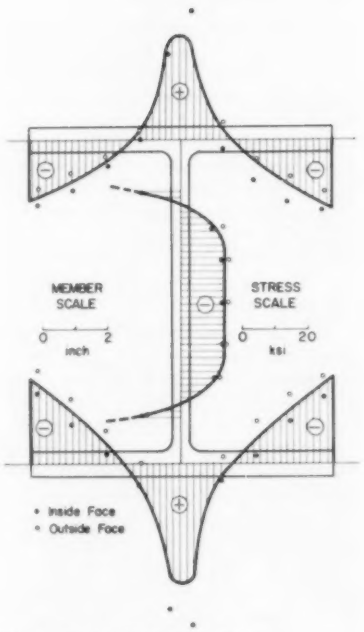


Fig. 1—Residual stress pattern in a welded H-shape

For the same welding conditions a wider heat affected zone is created in thinner plates than in thicker plates. Width of the plate is no great factor for the behavior of the proximity of the weld. It does however influence the general rise in temperature after welding. Spread of welding affects mostly the shape of the isotherm.[6]

Previous Research

The mathematical analysis for the magnitude and distribution of residual stresses in welded plates is very complicated and not exact. Simple cases have been analyzed based on approximate assumptions.

Early analytical work was carried

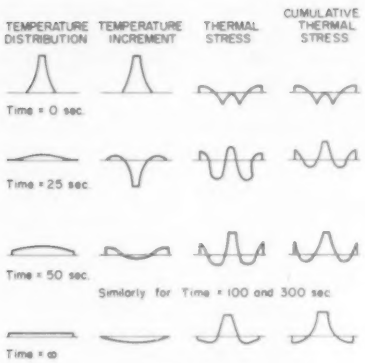


Fig. 2—Formation of residual stresses in a center-welded plate

out among others by Gruning,[7] Boulton and Lance Martin,[8] Rodgers and Fetcher[9] and, more recently, by Weiner.[10] As an example of early theories, Grüning assumed that the residual stress was equal to the thermal stress at the instant of welding, the thermal stress being limited by the yield strength of the material. This value of residual stress was approximately true since the thermal stresses at the instant of welding have the greatest influence on the resulting residual stress. Weiner has presented a rigorous solution to the three-dimensional plate, disregarding, however, the variation of mechanical properties with temperature.

Rosenthal made a detailed investigation of the temperature distribution resulting from welding and gave solutions for a number of cases.[6] The temperature distribution is a very necessary step in the calculation of residual stresses where greater accuracy is desired than afforded by the more approximate methods.

Residual stress distributions have been calculated for selected plates and welds in conjunction with this present study, and will be reported separately. Briefly, once the temperature distribution is obtained, the thermal stresses and hence the residual stresses can be calculated. This is not simple and must follow a step-by-step procedure since the material properties vary. The plate is assumed thin enough to be a two dimensional problem but this assumption is not valid for very thick plates.

The step-by-step method takes into account the complete history of cooling and the variation of material properties. At each step, the plastic deformation is considered and equilibrium accounted for, such that the complete history of stress throughout the cooling is obtained.

The method is approximate, however, because insufficient data is available for the material properties of steel at elevated temperatures. The above procedure as applied to a welded plate is represented pictorially in Fig. 2. The "temperature distribution" is indicated for each interval of time considered, time being measured from the instant of first deposition of weld. The "temperature increment" is the difference in temperature between successive time intervals considered. The "thermal stress" for any time interval is the stress created in the plate due to the temperature distribution of the temperature increment. The "cumulative thermal stress" gives the actual thermal stress at any time interval, and is the summation of all previous "thermal stresses" up to and including the time interval considered; the summation takes into account the material properties of steel at the elevated temperatures. The "cumulative thermal stress" at the time of infinity is the residual stress remaining in the plate.

The measurement of residual stresses in plates due to welding has been pursued almost since the beginning of modern welding. A few of the more recent studies will be mentioned:

Griffiths measured residual stresses transverse to joints made up by welding.[11] He used plates of size 4.1/2 x 48 x 5/8 in. and 12 x 36 x 5/8 in. and the magnitude of

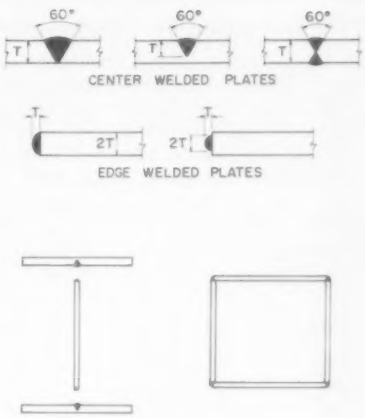


Fig. 3—Types of welds used to simulate conditions prevailing in welded H and box sections

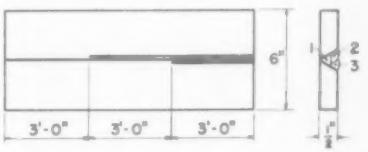


Fig. 4—Layout for multi-pass welding (Plate T-7-5)

Fig. 5—Layout of a typical test plate (Test T-5)

NOTE: 1, for coupons before welding; 2, 4, 6, for 1/4-in. 60° center-V welding; 3, for 1/8-in. 60° center-V welding; 5, for 1/4-in. edge welding, and 7, for 3/4-in. 60° center-V welding. Plates 2 through 7 are to be cut for residual stress measurement after welding. From plates 2, 3, and 7 coupons are to be cut after welding, of same size as from plate 1.

Table 1—Plate Sizes Tested

t\b	4	6	8	10	12	16	18	20
1/4	x o	x o + *	x o	..	..	..	..	..
3/8	..	o	..	..	..	..	..	..
1/2	..	o + *	o	x o *	o	x o + *	..	o
3/4	..	o	..	..	o + *	..	o	..
1	..	x o	..	..	o + *	o	..	x o

NOTE: All sizes given are in inches unless otherwise shown.
t, thickness of plate; b, width of plate; x, residual stress before welding; o, residual stress after welding; +, coupon tests before welding; *, coupon tests after welding.

Fig. 6—Typical welding arrangement

Table 2—Table of Tests (Data Grouped According to Plate Width)

Test no.	Plate size b, in.	Plate size t, in.	Residual stresses measured Before welding	Residual stresses measured After welding	Type and Depth of welding, (T) Single -Vee	Type and Depth of welding, (T) Double -Vee	Type and Depth of welding, (T) Edge	Coupon tests Before welding	Coupon tests After welding
T-4	4	1/4	x	x	1/4	..	..	..	..
T-1	6	1/4	x	x	1/8	..	..	..	..
				x	1/4	..	..	..	..
T-12	6	3/8	..	x	3/8	..	..	..	..
T-7	6	1/2	x	x	1/8	1/2	1/4	x	x
				x	2/3	..	..	..	..
T-15	6	3/4	..	x	..	3/4	..	..	..
T-17	6	1	x	x	1/2	..	..	..	..
T-8	8	1/4	x	x	..	..	1/8	..	..
T-3	8	1/2	..	x	1/4	..	1/8	..	..
				x	1/2	..	..	..	..
T-2	10	1/2	x	x	1/2	1/2	1/4	..	x
T-11	12	1/2	..	x	1/4	..	..	..	..
					1/2	..	..	..	..
T-5	12	3/4	..	x	1/4	..	1/8	x	x
				x	1/2	..			
				x	3/4	..	..	..	..
T-18	12	1	..	x	..	..	1/2	x	x
T-13	16	1/2	x	x	..	..	1/4	x	x
T-10	16	1	..	x	1/2	1	3/8	.	..
				x	3/4	..	..	..	..
T-16	18	3/4	..	x	3/8	3/8	3/8	..	..
T-14	20	1/2	..	x	1/2	..	1/4	..	..
T-6	20	1	x	x	..	..	3/8	..	..

Table 3—Table of Tests (Data Grouped According to Plate Thickness)

Test no.	Plate size t, in.	Plate size b, in.	Residual stresses measured Before welding	Residual stresses measured After welding	Type and depth of welding, (T) Single -V	Type and depth of welding, (T) Double -V	Type and depth of welding, (T) Edge	Coupon tests Before welding	Coupon tests After welding
T-4	1/4	4	x	x	1/4	..	..	..	..
T-1	1/4	6	x	x	1/8	..	..	x	x
				x	1/4	..	..	..	..
T-8	1/4	8	x	x	..	..	1/8	..	..
T-12	3/8	6	..	x	3/8	..	..	..	..
T-7	1/2	6	x	x	1/8	1/2	1/4	x	x
				x	3/4	..	..	..	..
T-3	1/2	8	..	x	1/4	1/2	1/8	..	..
				x	1/2	..	..	..	..
T-2	1/2	10	x	x	1/2	1/2	1/4	..	x
T-11	1/2	12	..	x	1/4	..	..	..	..
				x	1/2	..	..	..	..
T-13	1/2	16	x	x	..	..	1/4	x	x
T-14	1/2	20	..	x	1/2	..	1/4	..	..
T-15	3/4	6	..	x	..	3/4	..	..	..
T-5	3/4	12	..	x	1/4	..	1/4	x	x
				x	1/2	..	..	..	..
				x	3/4	..	..	..	..
T-16	3/4	18	..	x	3/8	3/4	3/8	..	..
T-17	1	6	x	x	1/2	..	..	..	..
T-18	1	12	..	x	..	..	1/2	x	x
T-10	1	16	..	x	1/2	1	5/8	..	..
				x	3/4	..	..	..	..
T-6	1	20	x	x	..	3/8	..	..	..

residual stress was observed to be 10 to 15 ksi. Also he found that the greatest value in tension was at a distance of 1 to 2 in. away from the line of weld.

Interesting results were obtained by Russian researchers[12] who measured residual stresses due to beads welded external to plates of size 6.9 x 24 x 0.43 in. and a center weld in a plate of size 5.8 x 19 x 0.43 in. They observed a stress of 40–44 ksi tension at the center and 9–25 ksi compression at the edges.

Wilson and Hao conducted tests on center-welded plates, 5 x 7/8 in. and 12 x 5/8 in.[5] The residual stress at the weld in the 5 in. wide plate was 34 ksi tension and 20 ksi compression at the edges. The corresponding stresses in the 12 in. wide plates were 48 and 18 ksi.

Meriam, DeGarmo and Jonassen found that cold working gradually reduced welding residual stresses.[13] They tested the redistribution of residual stresses by applying a tensile loading along a unionmelt weld joining two 3 ft x 12 ft x 1 in. plates.

Rosenthal and Norton perfected a method to find the exact distribution of triaxial residual stresses due to welding.[14]

Krefeld and Ingalls in their investigation on residual stresses in a butt-welded structural I-beam found that the distribution was similar to that in flat plates.[15]

Weck studied the residual stress distribution due to welding and concluded that stresses approaching the yield point were always found in the welded steel. He also stated that welding procedure was of little influence on the magnitude of the stresses.[16]

Gunnert[17] presented a method for measuring residual stresses in a very small localized region, as well as determining the direction of the principal stresses. The method is applicable to both the parent metal and the weld.

Fujita[18] presented experimental and theoretical results for both the temperature distribution and thermal and residual stresses arising during and after the center welding of plates. Tests on center-welded 10 x 1/2 in. plates showed residual stresses of 50 ksi tension at the center, 13 ksi compression at the edges, with the maximum compression stress of 25 ksi occurring about 2 in. from the edges.

Many other researchers conducted tests to determine residual stresses. However, no-one came to a conclusion or studied the variation due to the geometric properties of the plate itself.

The purpose of this study is to investigate the magnitude and distribution of residual stress in welded plates in order to present predictions for residual stress in plates which make up welded built-up sections. In order to accomplish this objective, the variation in geometry must be considered as well as the position of the weld.

Description of Tests

Types of Welds

Tests were planned so as to include plates of various sizes which would be expected to be generally used in built-up members. The selection of plates chosen encompassed a range larger than any hitherto tested in any single program. Table 1 shows the various sizes of plates used and the tests conducted on them. Tables 2 and 3 give the information available from each of the tests. Plates $^1/_8$ and $^3/_{16}$ in. thick were originally included in the program but were removed when it was found that they were not generally used in welded structures, nor were they readily available.

The plates were welded along either single or double Vee-grooves in the center, or along an edge so as to simulate conditions obtained in actual built-up shapes. One plate was welded on both edges. These welds simulated those on parts of H and box sections (Fig. 3).

The majority of the welds were multi-pass as would be the case for actual built-up shapes. However, residual stresses were measured on one welded plate to note the cumulative effect of single-, double- and triple-pass welds (Fig. 4, plate T-7-5). Figure 5 shows the layout of a typical test plate (plate T-5).

The plates were welded in the "Flat Position" by hand by experienced professional welders and all welding standards were adhered to. The plates were clamped to heavy structural columns of large cross section. There was no precambering since warping was not a criterion for these plates. The welding set up for a plate is shown in Fig. 6.

The speed of welding, type of electrode, current as well as any relevant details were recorded for each welded plate so that the experimental results could be correlated with analytical results if required. This information is given in Table 4.

The plates used in these tests were all bars or universal mill plates cold-straightened at the mill to be within specification tolerances as to straightness.

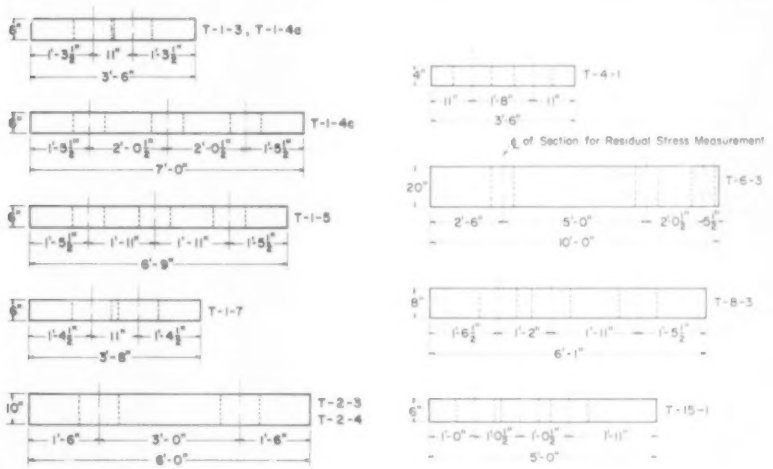


Fig. 7—Layout of plates for which residual stress was measured at more than one section

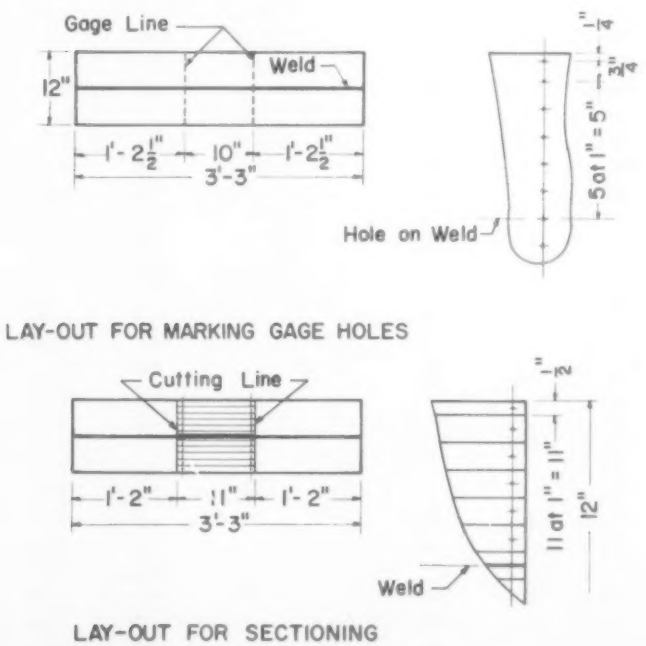


Fig. 8—Typical layout for marking and sectioning (Test T-11)

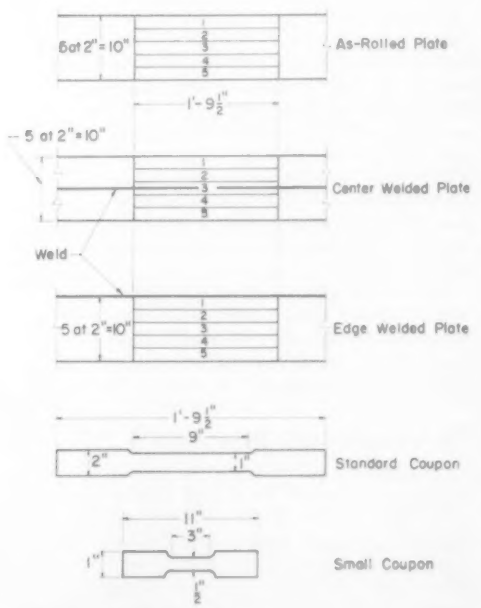


Fig. 9—Layout for coupons

Residual Stress Measurement

The plates used were sufficiently long so that a uniform state of stress would exist in the central portion where the longitudinal residual stresses were measured. Residual stress measurements were made on a 10 in. gage length, both ends of which were at a distance from the cut edge more than the width of the plate, which has been shown to satisfy the requirements for effect of boundary conditions in experimental and theoretical studies on rolled shapes.[2,3]

A few tests were conducted also to study the variation of residual stress along the length of the plate. Figure 7 shows the layout of plates for which residual stress was measured at more than one section.

Residual stresses were measured on nonwelded as-rolled plates to determine the distribution of residual stresses before welding. Residual stresses were measured by the "method of sectioning."[19] Gage holes were marked on the plates, the gage length was measured and the plate cut into pieces, as shown in Fig. 8 for a typical plate. Cutting relieved the stresses in the plate, and by measuring the gage length again, the change in length gave the elongation or shortening, from which the stress that was released could be found. It should be noted that this method gives the longitudinal residual stresses only, although by inference, the lateral residual stresses may be also obtained.

Coupon Tests

Coupon tests were conducted on tension coupons taken from plates before and after welding in order to obtain plate material properties. Figure 8 shows a typical lay-out of coupons cut from plates. To check the yield stress level of the material at the weld, tension tests were made on coupons of both the standard size and of a small size, shown in Fig. 9. The small coupon consisted almost entirely of weld material.

Tables 2 and 3 indicate from which plates the tension coupons were cut. The dimensions of the coupons were in accordance with ASTM specifications.[20]

Test Results and Discussion

The results of the tests are shown in Figs. 10 through 25 and in Tables 4–7. The illustrations are classified into two groups: plates with center welds and plates with edge welds. Wherever residual stresses were measured on nonwelded plates, they were shown with the corresponding

Table 4—Record of Rate of Application of Weld (Electrode used: AWS E6012. AIRCO 387 AC)

Machine used: rated at 500 Amp 40V. 60% duty cycle 90°C rise. 70V. open circuit

Test no. & plate	Size, in.	Type[a] & depth of weld, in.	Length of weld, in.	Pass no.	Diam of rod, in.	Current, amp	Electrode speed, ips[b]
T-1-1	6 x 1/4	V 1/8	24	1	2/32	100	0.20
				2	2/32	100	0.20
-2	6 x 1/4	V 1/4	24	1	3/16	375	0.12
-4	6 x 1/4	V 1/4	150	1	3/16	375	0.17
				2	3/16	375	0.16
				3	3/16	375	0.17
-7	6 x 1/4	V 1/8	68	1	2/32	100	0.28
				2	2/32	100	0.30
T-2-1	10 x 1/2	X	36	1[c]	3/16	375	0.12
				2[d]	3/16	375	0.13
-2	10 x 1/2	E 1/4	36	1	3/16	240	0.10
				2	3/16	240	0.13
				3	3/16	240	0.13
-3	10 x 1/2	X	72	1[e]	3/16	280	0.13
				2[d]	3/16	280	0.10
-4	10 x 1/2	E 1/4	72	1	3/16	240	0.10
				2	3/16	240	0.13
				3	3/16	240	0.15
-6	10 x 1/2	V 1/2	30	1	3/16	375	0.17
T-3-1	8 x 1/2	V 1/4	36	1	3/16	280	0.13
-2	8 x 1/2	X	36	1[c]	3/16	275	0.11
				2[d]	3/16	275	0.12
-3	8 x 1/2	V 1/4	36	1	3/16	280	0.13
-4	8 x 1/2	V 1/2	36	1	3/16	300	0.12
				2	3/16	375	0.12
				3	3/16	375	0.12
-5	8 x 1/2	V 1/4	36	1	3/16	280	0.11
-6	8 x 1/2	E 1/8	36	1	3/16	240	0.11
T-3-7	8 x 1/2	E 1/8	36	1[e]	3/16	240	0.10
				2[e]	3/16	240	0.11
-8	8 x 1/2	X	36	1	3/16	275	0.12
				2	3/16	275	0.13
-9	8 x 1/2	V 1/2	28	1	3/16	375	0.14
T-4-1	4 x 1/4	V 1/4	42	1	3/16	275	0.09
T-5-2	12 x 3/4	V 1/4	59	1	3/16	285	0.08
-3	12 x 3/4	V 1/2	59	1	3/16	410	0.08
				2	3/16	410	0.06
-4	12 x 3/4	V 1/4	38	1	3/16	285	0.08
-5	12 x 3/4	E 1/4	38	1	3/16	425	0.10
-6	12 x 3/4	V 1/4	38	1	3/16	275	0.20
				2	3/16	275	0.10
-7	12 x 3/4	V 3/4	59	1	1/4	410	0.14
				2	1/4	410	0.12
				3	1/4	410	0.10
				4	1/4	410	0.08
				5	1/4	410	0.23
T-6-1	20 x 1	E 3/8	60	1	3/16	240	0.11
				2	3/16	240	0.12
				3	3/16	240	0.15
-3	20 × 1	E 3/8	120	1	3/16	240	0.12
				2	3/16	240	0.14
				3	3/16	240	0.18
T-7-2	6 x 1/2	V 1/8	30	1	1/8	140	0.11
-3	6 x 1/2	X	30	1[c]	3/16	285	0.08
				2[d]	3/16	285	0.08
-4	6 x 1/2	E 1/4	40	1	3/16	275	0.07
-5	6 x 1/2	V 3/8	108	1	1/8	190	0.18
			72	2	1/8	190	0.11
			36	3	1/8	190	0.07

Table 4—(Continued)

Test no. & plate	Size, in.	Type[a] & depth of weld, in.	Length of weld, in.	Pass no.	Diam of rod, in.	Current, amp	Electrode speed, ips[b]
T-8-1	8 x 1/4	E 1/8	36	1	5/32	110	0.42
-2	8 x 1/4	E 1/8	73	1	5/32	110	0.38
T-10-1	16 x 1	V 1/2	44	1	3/16	260	0.15
				2	3/16	260	0.09
				3	3/16	260	0.07
-2	16 x 1	V 3/4	44	1	3/16	260	0.17
				2	1/4	325	0.14
				3	1/4	325	0.11
				4	1/4	325	0.07
				5	1/4	325	0.06
-3	16 x 1	X	44	1[f]	3/16	200	0.17
				2	3/16	250	0.15
				3	3/16	250	0.17
				4	3/16	250	0.10
				5	3/16	250	0.07
				6	3/16	250	0.07
				7	3/16	250	0.07
-4	16 x 1	E 3/8	44	1	1/4	240	0.19
				2	1/4	240	0.18
				3	1/4	240	0.14
T-11-1	12 x 1/2	V 1/4	39	1	5/32	150	0.15
				2	5/32	200	0.11
-2	12 x 1/2	V 1/2	39	1	3/16	260	0.17
				2	3/16	260	0.11
				3	3/16	260	0.09
T-12	6 x 3/8	V 3/8	30	1	5/32	230	0.16
				2	5/32	230	0.09
T-13-2	16 x 1/2	E 1/4	75.5	1	3/16	175	0.18
				2	3/16	175	0.23
				3	3/16	175	0.23
T-14-1	20 x 1/2	V 1/2	60	1	3/16	250	0.14
				2	1/4	300	0.13
				3	1/4	300	0.07
-2	20 x 1/2	E 1/4	60	1	3/16	200	0.12
T-15-1	6 x 3/4	X	60	1[g]	5/32	150	0.14
				2	3/16	250	0.13
				3	3/16	250	0.10
				4	3/16	250	0.10
				5	3/16	250	0.07
T-16-1	18 x 3/4	V 3/8	54	1	5/32	230	0.18
				2	3/16	250	0.15
				3	3/16	250	0.08
-2	18 x 3/4	X	54	1[g]	5/32	230	0.16
				2	3/16	250	0.14
				3	3/16	250	0.09
				4	5/32	250	0.13
				5	3/16	250	0.07
-3	18 x 3/4	E 3/8	54	1	3/16	200	0.19
				2	3/16	200	0.20
				3	3/16	200	0.12
T-17-2	6 x 1	V 1/2	30	1	3/16	250	0.14
				2	3/16	250	0.09
				3	3/16	250	0.05
T-18-2	12 x 1	E 1/2	63	1	3/16	200	0.16
				2	3/16	200	0.17
				3	1/4	300	0.11
				4	1/4	300	0.19

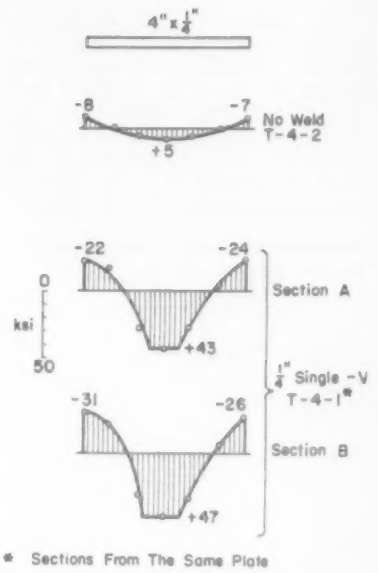


Fig. 10—Residual stress distribution, 4- x 1/4-in. plate

welded plate. The size of the weld is indicated in each of the stress patterns. The tables give information as to the plate size and weld size, as well as welding details; the yield stress level is shown and each residual stress distribution is tabulated.

The distribution of residual stress for all nonwelded plates is approximately parabolic; this is true also for all but the very wide welded plates.

For nonwelded plates, the maximum tensile residual stress varied from 1 to 9 ksi and had an average value of about 4.5 ksi. The compressive residual stress at the edges varied from 3 to 17 ksi and had an average value of about 7 ksi. These residual stresses are formed in the plate due to plastic deformations from cooling after rolling. Plate T-7 (Fig. 12) was the only one for the whole investigation in which the cold-straightening of the plate was indicated by the residual stress measurement. The straightening relieves residual stresses[10] and this is the reason for the absence of appreciable amounts of residual stresses in Plate T-7 (Fig. 12).

[a] V = single- V, X = double- V, E = edge.
[b] Units for analytical investigation.
[c] Side welded first.
[d] Side welded second.
[e] Both the edges are welded, one after another.
[f] Numbers indicate order of welding; 1, 2, 6, and 7 on one side; 3, 4 and 5 on the other side.
[g] Passes, 1, 2, 3 on one side; 4 and 5 on the other side.

For plates welded along the centerline with a single Vee- or a double Vee-weld, the residual stress pattern is the same, showing that the heat input, rather than the shape of the weld is the prime factor for the formation of the residual stresses, although heavier welds give slightly higher stresses. See Fig. 14, Plate T-3. In all cases, the areas of tensile and compressive stresses are equal, indicating that the residual stess measurements and methods are reliable. (However in Fig. 19) the areas do not appear to balance as the plate was thick and measurements were made on one side only.) The residual stress at the welds is seen to be far above the yield strength of the base material, sometimes as high as 80 ksi, but usually about 50% above the yield strength. Such a high stress is recorded on, or in the close vicinity of the weld metal, the parent plate material not being able to withstand a stress higher than its yield strength.

The stress patterns are symmetrical about the weld. For wide plates (greater than about 16 in.)

Table 5—Results of Coupon Tests

Test no.	Before welding: Plate no.[d]	Coupon no.	σ_{ys}, ksi	After welding: Plate no.[a]	Coupon no.	σ_{ys}, ksi	Ductility: Elongation, %	Reduction in area, %
T-1	6	2	42.2	4B	1	41.9	..	..
		4	41.2		2	46.8[b]	..	..
		9	41.6		3	41.7	..	..
				7	1	41.9	..	..
					2	45.0[b]	..	..
					3	41.4	..	..
T-2	..	..	..	3	1	36.6	..	..
					2	34.6	..	..
					3	43.4[b]	..	..
					4	34.3	..	..
					5	35.7	31.2	59.0
				3[c]	A2	34.5	..	..
					A5	54.8[b]	22.0	36.7
					A8	34.6	..	..
					B2	34.8	..	..
					B5	55.3[b]	9.3	30.5
					B8	34.7	..	..
				6[c]	2	33.1	..	..
					5	52.7[b]	18.7	27.6
					8	33.5	..	..
T-5	1	1	27.9	2	1	28.1		
		2	26.0		2	34.9[b]		
		3	25.6		3	28.7		
		4	25.6	3	1	29.3		
		5	26.2		2	42.3[b]		
		6	28.0		3	29.5		
				7	1	30.0		
					2	45.8[b]		
					3	30.1		
T-7	1	1	35.5					
		2	36.4					
T-13	1	1	35.6	2	W1	33.5		
		2	34.2		W2	34.8		
		3	35.7		W3	34.8		
		4	34.7		W4	35.0		
		5	34.9		W5	35.2		
		6	35.4		W6	35.0		
		7	35.1		W7	35.2		
		8	34.5		W8	34.3		
T-18[d]	2	A1	30.3	2	B1	28.6[e]		
		A2	28.8		B2	29.3		
		A3	28.5		B3	28.7		
		A4	28.3		B4	28.8		
		A5	28.7		B5	29.0		
		A6	29.7		B6	30.0		

[a] Plate numbers indicate portions of plate cut from the same test piece which is designated by a test number.
[b] This coupon includes weld metal.
[c] All coupons cut from these plates are small coupons (nonstandard).
[d] This plate edge welded.
[e] This coupon from material nearest to weld edge.

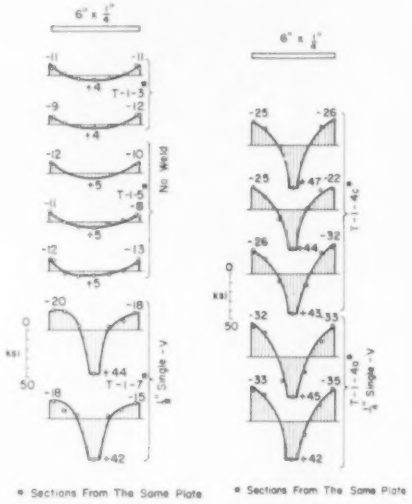


Fig. 11—Residual stress distribution, 6- x 1/4-in. plate.

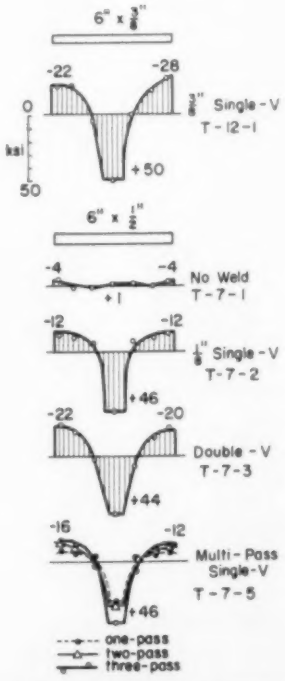


Fig. 12—Residual stress distribution, 6- x 3/8-in. and 6- x 1/2-in. plates

and heavy welds, the plates develop tensile residual stresses at the edges as shown in Fig. 18 (Plate T-10). For medium width plates, the stresses at the edges are compressive and their magnitude does not appear to depend on the geometrical properties of the plate, but rather on the depth and size of the weld—Figs. 14 through 17, Plates T-2, 3, 5 and 11.

The residual stress patterns for edge-welded plates are similar in all cases and show a high tensile stress at the welded edge, similar to the stress along the weld in center-welded plates. At the remote edge the tensile residual stress is about 8 ksi. On wide plates (approximately greater than 16 in.) the remote edge may develop compressive residual stresses as in Plates T-6, 10, 14, and 16, Figs. 24 and 25. The reversal of stresses at the far edge probably occurs since moment equilibrium of residual stresses has to be maintained internally, to compensate for the unsymmetrical heat input and temperature distribution.

The effect of one-, two- and three-passes of weld is shown for the centrally welded plate, Fig. 12, Plate T-7. There is surprisingly little difference between the residual stress distribution due to successive passes, although the residual stress magnitude does increase somewhat with each additional pass. This shows that residual stress magnitude is not a direct ratio of the heat input, the first application of heat having the greatest effect. This may be understood when one realizes that the yield properties of the material have a very definite boundary which can be exceeded only slightly by the changes wrought by the heat of deposition. The above only applies to medium size plates with few passes of weld, a greater difference or number of passes will show up in the magnitude of the residual stresses away from the weld, rather than at the weld.

Welding changes the material properties of the plate only in the vicinity of the weld. The most important change is that the yield stress level is increased, which requires a corresponding increase in residual stress elsewhere in the distribution. To check the yield stress level at the weld, tension tests were run on both standard and small coupons. The results were in good agreement, however, except that the ductility of the small coupons containing the weld was decreased. The yield stress levels of the materials tested before and after welding are given in Table 5 and are taken from coupon tests and indicate these facts.

Residual stress patterns across

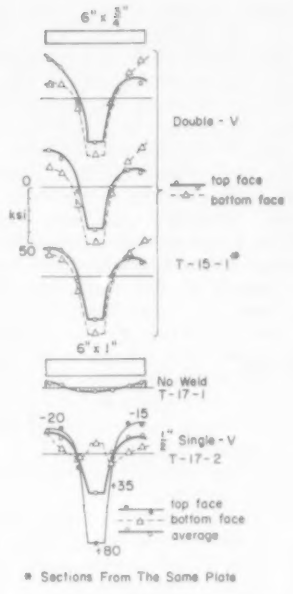


Fig. 13—Residual stress distribution, 6- x 3/4-in. and 6- x 1-in. plates

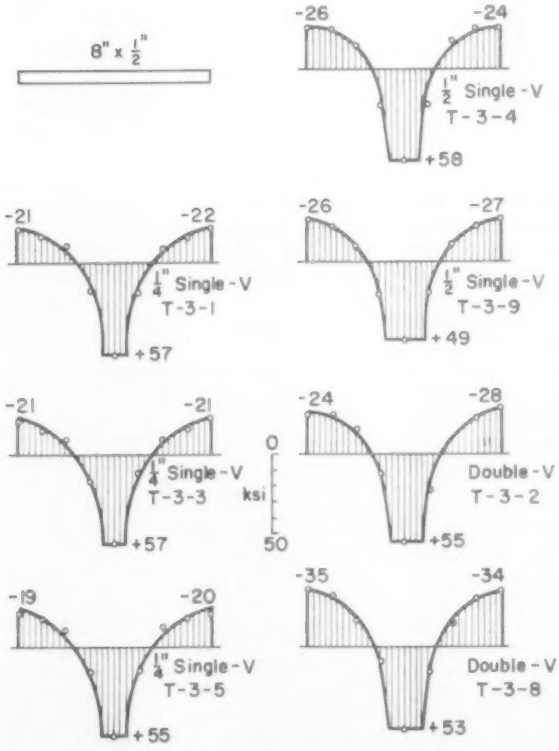


Fig. 14—Residual stress distribution, 8- x 1/2-in. plate

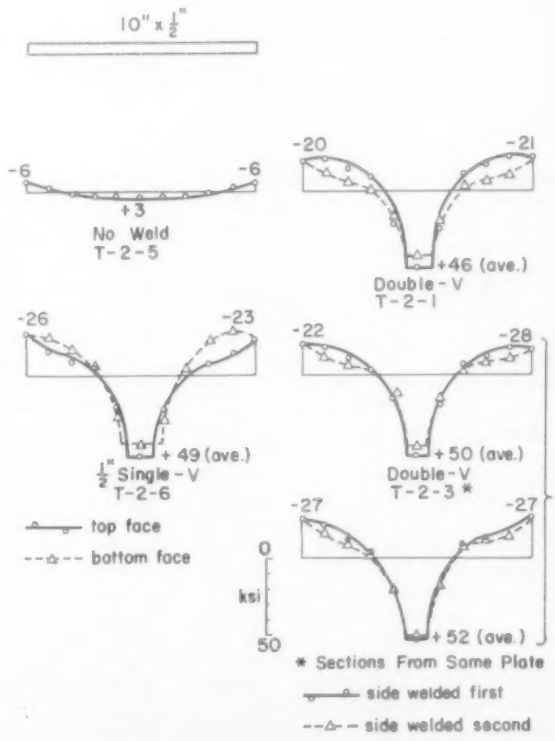


Fig. 15—Residual stress distribution, 10- x 1/2-in. plate

different sections of the same plate are shown in Fig. 11 for Plate T-1, for the nonwelded and single-Vee center welded cases; also in Fig. 13 for Plate T-15 for a double-Vee weld along the center line, and in Figs. 21 and 25 for Plates T-8 and T-6 which were edge welded. There is very little difference between the stress patterns for each type. Hence, it can be concluded that the residual stresses are uniform along the length of the plate, and that the tests and measurements satisfy St. Venant's principle for boundary conditions. The latter conclusion may be made because the center section in any series is far removed from the edges, yet the distribution there agrees well with that of the end section which could be affected by end conditions.

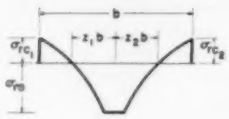
It is noted that, for thick plates, the residual stress distribution for each side differs appreciably—Fig. 13, Plates T-15 and T-17. This shows that there is a limitation to the thickness of a plate for the residual stresses to be regarded as two dimensional in the plate. From the measurements of this program of tests, it is found that plates thinner than $^1/_2$ in. show the same longitudinal residual stresses on both faces. (This is basically a problem of uniformity of temperature distribution, which has been considered theoretically,[6] it being found that plates less than about $^7/_{16}$ in. may be regarded as two dimensional for temperature distribution purposes.) The variation of residual stresses though the thickness of the plate was not measured.

The salient dimensions of the residual stress distributions for all the plates have been enumerated in Table 6 and 7. These tables have been derived on the assumption that $\sigma_y = 33$ ksi for each plate.[19] For purposes of preduction of residual stresses, the plate sizes have been divided into three groups, less than 8 in., 8 to 14 in. and 16 to 20 in., called "narrow," "medium" and "wide" plates. The residual stress magnitudes are shown against the weld size, for each test. Average experimental values of residual stresses are shown as predicted values for each of these groups in Table 8. As a result of the investigation, it is possible to estimate the distribution and magnitude of residual stresses in welded plates, as shown in Table 8. As an example, for a medium plate with a weld at the center the residual stress would be about 52 ksi tension at the center and about 23 ksi compression at the edges. Similar predictions can be made for other plates, both edge and center welded.

All the welding in this investigation was carried out manually and usually consisted of two or three passes. No automatic welds were made; automatic welds will be considered in a future study.

Generally speaking, the residual stress distributions for various plate sizes given in the literature agree well with those of this investigation. Whereas mainly "wide" plates have been considered by other investigators previously, this study covered a wide sample of all plate sizes. Since the influence of residual stress on column strength had not been realized before, this series of tests is the first to systematically tabulate residual stress distributions arising in plates making up welded built-up shapes with a view to utilizing the results in column strength predictions.

Table 6—Residual Stress Distribution in Center Welded Plates



Assumption: $\sigma_y = 33$ ksi

Test no.	Plate no.	Plate size	T	$\frac{\sigma_{ro}}{\sigma_y}$	$\frac{\sigma_{rc_1}}{\sigma_y}$	$\frac{\sigma_{rc_2}}{\sigma_y}$	Residual stress coefficients Mean	Positions of zero residual stress z_1	z_2	Mean
Narrow plates										
T-4	1	4 x $^1/_4$	$^1/_4$	1.30	0.67	0.73	0.70	0.24	0.31	0.275
	1	4 x $^1/_4$	$^1/_4$	1.42	0.94	0.79	0.87	0.22	0.28	0.250
T-1	7	6 x $^1/_4$	$^1/_8$	1.33	0.61	0.55	0.58	0.17	0.16	0.165
		6 x $^1/_4$	$^1/_8$	1.27	0.55	0.45	0.50	0.18	0.17	0.175
	4c	6 x $^1/_4$	$^1/_4$	1.42	0.76	0.79	0.78	0.18	0.19	0.185
		6 x $^1/_4$	$^1/_4$	1.33	0.76	0.67	0.72	0.20	0.17	0.185
		6 x $^1/_4$	$^1/_4$	1.30	0.79	0.97	0.88	0.19	0.20	0.195
	4a	6 x $^1/_4$	$^1/_4$	1.36	0.97	1.00	0.99	0.18	0.19	0.185
		6 x $^1/_4$	$^1/_4$	1.27	1.00	1.06	1.03	0.15	0.21	0.180
T-12	1	6 x $^3/_8$	$^3/_8$	1.51	0.67	0.85	0.76	0.18	0.17	0.175
T-7	5	6 x $^1/_2$	1 pass	0.91	0.24	0.24	0.24	0.15	0.16	0.155
			2 pass	1.00	0.45	0.33	0.39	0.19	0.16	0.175
			3 pass	1.42	0.45	0.39	0.42	0.17	0.19	0.180
T-7	2	6 x $^1/_2$	$^1/_8$	0.79	0.36	0.42	0.39	0.15	0.15	0.150
	3	6 x $^1/_2$	X	0.73	0.67	0.61	0.64	0.18	0.19	0.185
T-15	1	6 x $^3/_4$	X[a]	1.24	1.03	0.42	0.73	0.15	0.18	0.165
			X[b]	1.55	0.22	1.06	0.64	0.20	0.19	0.195
			X[a]	1.15	1.06	0.39	0.73	0.17	0.17	0.170
			X[b]	1.67	0.55	1.03	0.79	0.22	0.19	0.205
			X[a]	1.18	0.76	0.36	0.56	0.17	0.18	0.175
			X[b]	1.58	0.61	0.94	0.78	0.21	0.18	0.195
T-17	2	6 x 1	$^1/_2$	2.42	0.73	0.82	0.78	0.18	0.17	0.175
Medium plates										
T-3	1	8 x $^1/_2$	$^1/_4$	1.73	0.64	0.67	0.66	0.19	0.19	0.190
	3	8 x $^1/_2$	$^1/_4$	1.73	0.64	0.64	0.64	0.20	0.19	0.195

Summary

This section summarizes the results of an experimental investigation into the magnitude and distribution of longitudinal residual stresses arising in plates due to edge and center welding. The results of this study will be used in the determination of the influence of residual stress on the strength of welded built-up columns.

The plates are of ASTM Designation A7 structural steel, welded manually. The plates vary in width from 4 to 20 in. and in thickness from $^1/_4$ to 1 in.

1. The distribution of residual stress in all plates, whether due to cooling from rolling in the unwelded plates, or due to cooling from welding in the welded plates, is approximately parabolic in shape, except at the weld itself. This is true for welded plates up to about 16 in. in width (Fig. 10 through 25).

Table 6 (Continued)

Assumption: $\sigma_y = 33$ ksi

Test no.	Plate no.	Plate size	T	$\frac{\sigma_{ro}}{\sigma_y}$	Residual stress coefficients $\frac{\sigma_{re_1}}{\sigma_y}$	$\frac{\sigma_{re_2}}{\sigma_y}$	Mean	Positions of zero residual stress Z_1	Z_2	Mean
	5	8 x 1/2	1/4	1.67	0.58	0.61	0.60	0.21	0.19	0.200
	4	8 x 1/2	1/2	1.76	0.79	0.73	0.76	0.17	0.16	0.165
	9	8 x 1/2	1/2	1.49	0.79	0.82	0.81	0.19	0.19	0.190
	2	8 x 1/2	X	1.67	0.76	0.88	0.82	0.17	0.18	0.175
	8	8 x 1/2	X	1.61	1.06	1.06	1.06	0.16	0.16	0.160
T-2	6	10 x 1/2	1/2[a]	1.36	0.79	0.76	0.78	0.18	0.17	0.175
			1/2[b]	1.61	0.79	0.76	0.78	0.17	0.21	0.190
	1	10 x 1/2	[a]	1.24	0.61	0.70	0.66	0.15	0.15	0.150
			X[b]	1.51	0.61	0.70	0.66	0.20	0.20	0.200
	3	10 x 1/2	[a]	1.42	0.67	0.85	0.76	0.17	0.17	0.170
			X[b]	1.64	0.67	0.85	0.76	0.18	0.18	0.180
			[a]	1.55	0.82	0.82	0.82	0.19	0.15	0.170
			X[b]	1.64	0.82	0.82	0.82	0.20	0.16	0.180
T-11	1	12 x 1/2	1/4	1.58	0.45	0.30	0.38	0.15	0.13	0.140
	2	12 x 1/2	1/2	1.42	0.51	0.24	0.38	0.16	0.14	0.150
T-5	2	12 x 3/4	1/4	1.64	0.42	0.76	0.59	0.16	0.16	0.160
	4	12 x 3/4	1/4	1.49	0.49	0.42	0.46	0.17	0.17	0.170
	6	12 x 3/4	1/4	1.67	0.49	0.30	0.40	0.16	0.17	0.165
	3	12 x 3/4	1/2	1.67	0.91	0.85	0.88	0.19	0.19	0.190
	7	12 x 3/4	3/4	1.70	0.67	0.61	0.64	0.20	0.20	0.200
Wide plates										
T-10	1	16 x 1	1/2	2.12	−0.79	−0.73	−0.76	0.10	0.10	0.100
	2	16 x 1	3/4[a]	1.27	1.09	1.09	1.09	0.10	0.11	0.105
			3/4[b]	1.82	0.58	0.55	0.57	0.17	0.14	0.155
	3	16 x 1	X	1.88	−0.18	−0.30	−0.24	0.12	0.10	0.110
T-16	1	18 x 3/4	3/8	2.12	0	0	0	0.24	0.22	0.230
	2	18 x 3/4	X	1.67	0.52	0.30	0.41	0.14	0.13	0.135
T-14	1	20 x 1/2	1/2	1.52	0.64	0.15	0.40	0.11	0.10	0.105

[a] Corresponds to the top surface of the plate.
[b] Corresponds to the bottom surface of the plate.

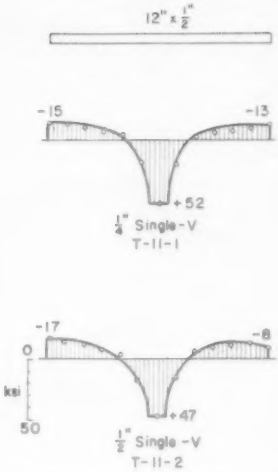


Fig. 16—Residual stress distribution, 12- x 1/2-in. plate

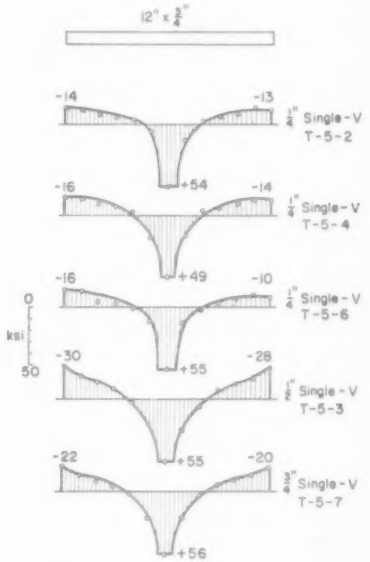


Fig. 17—Residual stress distribution, 12- x 3/4-in. plate

2. There is no great variation of residual stress in welded plates between successive passes, and the first pass causes the majority of the residual stress. At the edge however, the effect of succeeding passes of weld is marked. (Fig. 12).

3. Where the welding conditions are uniform along a plate, the residual stresses are also uniform along the length of the plate (Fig. 11, 12, 13, 20, 21 and 24).

4. Residual stresses in welded plates can be measured accurately in a section to within a distance of the width of the plate from a cut edge. This is in confirmation of experimental and theoretical studies on rolled shapes.

5. Welding changes the material properties of the plate only in the vicinity of the weld. The most important change is that the yield stress level is increased about 50%, which requires a proportionate increase in the compressive residual stress elsewhere in the distribution (Table 5).

6. Plates smaller than 1/2 in. in thickness show the same longitudinal residual stresses on both faces.

7. The results of this study make it possible to predict approximately the residual stress magnitude and distribution for welded plates (Table 8). As an example, for a 10 in. wide plate with a weld along the centerline, the residual stress would be about 52 ksi tension at the center and about 23 ksi compression at the edges.

Nomenclature

b = width of the plate.
E = symbol for edge weld.
t = thickness of plate.
T = depth of weld.
V = single-Vee groove weld.
X = double-Vee groove weld.
z_1, z_2 and z_3 = parameters in terms of "b" used to express the distance of the points where residual stresses are zero or maximum (compressive).
σ_y = yield point, yield strength or yield stress level.
σ_{yo} = static yield stress level (zero strain rate).
σ_{ro} = residual stress at the center of the center welded plate.
σ_{re} = residual stress at the edge of the center welded plate.
σ_{rt} = residual stress at the welded edge of the edge welded plate.
σ_{rm} = maximum compressive residual stress in the edge welded plate.
σ_{rf} = residual stress at the nonwelded edge of the edge welded plate.

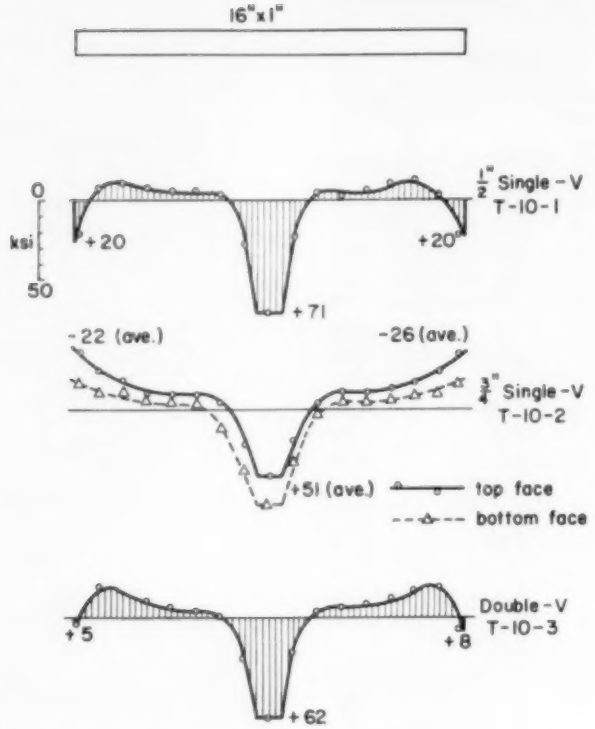


Fig. 18—Residual stress distribution, 16- x 1-in. plate

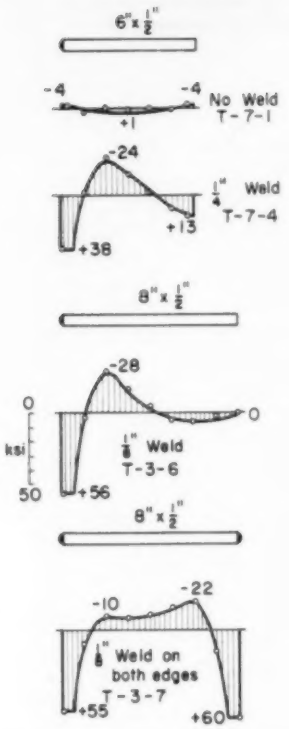


Fig. 20—Residual stress distribution, 6- x 1/2-in. and 8- x 1/2-in. plates

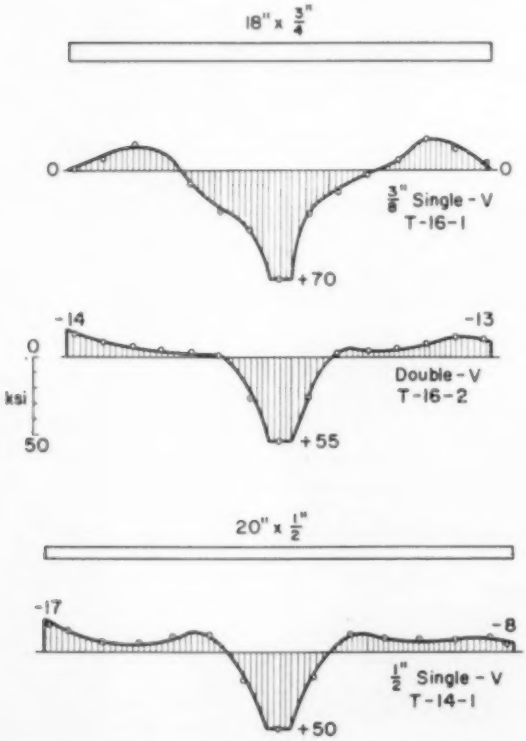


Fig. 19—Residual stress distribution, 18- x 3/4-in. and 20- x 1/2-in. plates

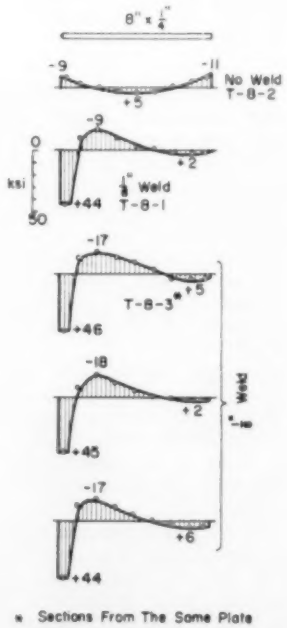


Fig. 21—Residual stress distribution, 8- x 1/4-in. plate

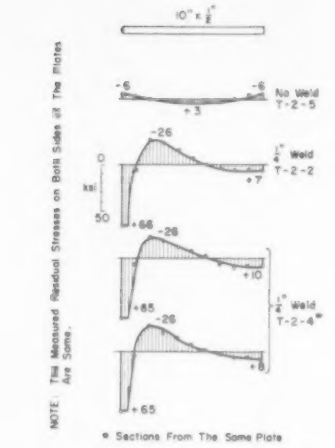


Fig. 22—Residual stress distribution, 10- x 1/2-in. plate.

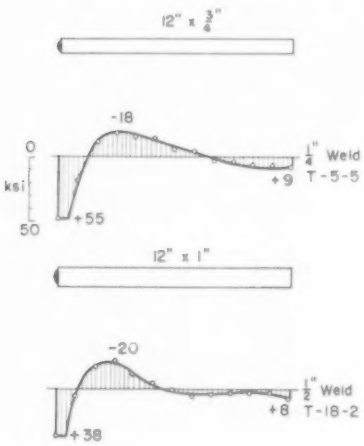


Fig. 23—Residual stress distribution, 12- x 3/4-in. and 12- x 1-in. plates

Definitions

Yield Point: The stress at which a noticeable increase in strain occurs without increase in stress.[20]

Yield Strength: The stress corresponding to the load which produces in a material, under the specified conditions of the test, a specified limiting plastic strain.[20]

Yield Stress Level: The average stress during actual yielding in the plastic range. It remains fairly constant for structural steel provided the strain rate remains constant. (Practically speaking, this means the stress at 0.5% strain.)

Acknowledgments

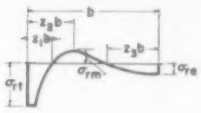
This report summarizes a part of the theoretical and experimental studies made during the course of a research program on the influence of residual stress on column strength carried out at the Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa.

The Pennsylvania Department of Highways and the U. S. Department of Commerce Bureau of Public Roads, the National Science Foundation, and the Engineering Foundation through the Column Research Council sponsor jointly the research program.

Lynn S. Beedle directed the project, and a Column Research Council Task Group under the chairmanship of John A. Gilligan has provided valuable guidance.

Acknowledgment is also due to Diethelm K. Feder and George J. Tamaro whose advice and assist-

Table 7—Residual Stress Distribution in Edge Welded Pates



Test no.	Plate no.	Plate size	T	Residual stress coefficients σ_{rt}/σ_y	σ_{rm}/σ_y	σ_{re}/σ_y	Assumption: $\sigma_y = 33$ ksi Positions of zero and maximum compressive residual stress z_1	z_2	z_3
Narrow plates									
T-7	4	6 x 1/2	1/4	1.12	0.70	0.42	0.158	0.292	0.334
T-8	1	8 x 1/4	1/8	1.33	0.48	0.00	0.125	0.362	0.250
	3	8 x 1/4	1/8	1.39	0.52	0.09	0.100	0.312	0.250
		8 x 1/4	1/8	1.36	0.55	0.12	0.112	0.312	0.250
		8 x 1/4	1/8	1.42	0.52	0.15	0.112	0.400	0.220
T-3	6	8 x 1/2	1/8	1.70	0.79	0.00	0.137	0.438	0.250
				1.66	0.27	...	0.162	...	0.240
	7*	8 x 1/2	1/8	1.82	0.58	...	0.162	...	0.260
Medium plates									
T-2	2	10 x 1/2	1/4	1.97	0.79	0.18	0.105	0.400	0.225
	4	10 x 1/2	1/4	1.97	0.67	0.27	0.110	0.380	0.221
		10 x 1/2	1/4	1.94	0.79	0.24	0.100	0.400	0.210
T-5	5	12 x 3/4	1/4	1.45	0.54	0.21	0.121	0.354	0.271
T-18	2	12 x 1	1/2	1.09	0.64	0.21	0.091	0.522	0.239
Wide plates									
T-13	2	16 x 1/2	1/4	1.21	0.36	0.67	0.072	0.484	0.141
T-10	3	16 x 1	3/8	1.15	0.48	..	0.063	0.563	0.119
T-16	3	18 x 3/4	3/8	1.36	0.45	—0.36	0.097	0.506	0.200
T-14	2	20 x 1/2	1/4	1.21	0.45	—0.33	0.070	0.520	0.137
T-6	1	20 x 1	3/4	1.18	0.36	—0.60	0.068	0.500	0.150
	3	20 x 1	3/4	1.33	0.49	—0.45	0.060	0.675	0.125
		20 x 1	3/4	1.27	0.52	—0.33	0.058	0.650	0.137
		20 x 1	3/4	1.15	0.3b	—0.24	0.050	0.682	0.115

* This plate was welded at both edges.

Table 8—Average of Experimental Values of Residual Stress Distribution in Welded Plates

Center welded plates

Plates	Nos. of measurements	σ_{ro}, ksi	σ_{rc}, ksi	Distance from ℄ of plate to zero residual stress (mean of z_1 and z_2)
Narrow	22	44	22	0.186
Medium	22	52	23	0.176
Wide	7	58	7	0.134

Edge welded plates

Plates	Nos. of measurements	σ_{rt}, ksi	σ_{rm}, ksi	σ_{re}, ksi	Positions of zero and maximum compressive residual stress z_1	z_2	z_3
Narrow	6	46	19	5	0.124	0.259	0.127
Medium	5	55	23	7	0.105	0.233	0.411
Wide	8	41	14	7	0.067	0.141	0.573

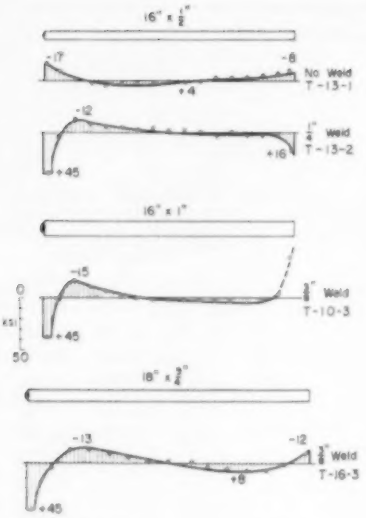


Fig. 24—Residual stress distribution, 16- x 1/2-in. 16- x 1-in. and 18- x 3/4-in. plates

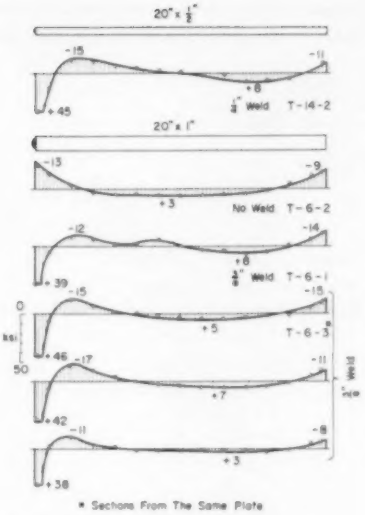


Fig. 25—Residual stress distribution, 20- x 1/2-in. and 20- x 1-in. plates

ance with this investigation has been invaluable.

References

1. Column Research Council, "The Basic Column Formula," Tech. Memo. No. 1 (May 1952).

2. Huber, A. W., "Residual Stresses in Wide-Flange Beams and Columns," Fritz Laboratory Report 220A.25, Lehigh University (July 1959).

3. Beedle, L. S., and Tall, L., "Basic Column Strength," ASCE Proc. Paper 2555, 86(ST7), July 1960, p. 139.

4. Feder, D. K., and Lee, G. C., "Residual Stresses in High Strength Steel," Fritz Laboratory Report 269.2, Lehigh University (April 1959).

5. Wilson, W. W., and Hao, C. C., "Residual Stresses in Welded Structures," Bulletin No. 361, University of Illinois (February 1946).

6. Rosenthal, D., "Mathematical Theory of Heat Distribution During Welding and Cutting," THE WELDING JOURNAL, **20** (5), Research Suppl., 220-s to 224-s (1941).

7. Grüning, M., "Die Schrumpfspannungen Beim Schweissen," Der Stahlbau (July 1934).

8. Boulton and Lance Martin, "Residual Stresses in Arc-Welded Plates," *Proc. Inst. Mech. Engrs. (London)*, **133**, 295-347 (1936).

9. Rodgers and Fetcher, "The Determination of Internal Stresses from the Temperature History of a Butt-Welded Plate," THE WELDING JOURNAL **17** (11), Research Suppl., 4-s to 7-s (1938).

10. Weiner, J., "An Elastoplastic Thermal Stress Analysis of a Free Plate," *Jnl. Appl. Mechanics*, **23** (3) (September 1956).

11. Griffiths, George H. R., "Residual Stresses in Butt-Welded Steel Plates," THE WELDING JOURNAL, **20** (9), Research Suppl., 410-s to 414-s (1941).

12. Cordovi, M. A., "Behaviour of Residual Stresses under External Load and Their Effect on Strength of Welded Structures," (by Acad. E. O. Patton, Prof. B. M. Gorbounov and Ing. D. O. Bershtein, Ukranian Academy of Sciences, Kiev 1937, translated and abstracted from Russian literature), *Ibid.*, **23** (9), Research Suppl., 473-s (1944).

13. Meriam, J. L., DeGarmo, E. Paul, and Jonassen, Finn, "Redistribution of Residual Welding Stresses by Tensile Loading along a Unionmelt Weld Joining Two 3-Ft x 12-ft x 1-in. Plates," *Ibid.*, **25** (10), Research Suppl., 697-s to 699-s (1946).

14. Rosenthal, D., and Norton, J. T., "A Method of Measuring Tri-Axial Residual Stress in Plates," *Ibid.*, **24** (5), Research Suppl., 295-s to 307-s (1945).

15. Krefeld, W. J., and Ingalls, E. C., "Residual Stresses in a Butt-Welded Structural I-Beam," *Ibid.*, **27** (8), Research Suppl., 417-s to 420-s (1948).

16. Weck, R., "Residual Stresses due to Welding," *Ibid.*, **28** (1), Research Suppl., 9-s to 14-s (1949).

17. Gunnert, R., "Residual Welding Stresses," Almqvist and Wiksell, Stockholm (1955).

18. Fujita, Y., "Built-Up Column Strength," Ph.D. Dissertation, Lehigh University (August 1956).

19. Huber, A. W., and Beedle, L. S., "Residual Stress and the Compressive Strength of Steel," THE WELDING JOURNAL, **33** (12), Research Suppl., 589-s to 614-s (1954).

20. ASTM Specification No. A370-55T.

21. Huber, A. W., "The Influence of Residual Stress on the Instability of Columns," Ph.D. Dissertation, Lehigh University (May 1956).

22. Tall, L., and Ketter, R. L., "On the Properties of Structural Steel Shapes," Fritz Laboratory Report 220A.33, Lehigh University (November 1958)

EUROPEAN WELDING RESEARCH

(*Continued from page 458-s*)

for the sensitization of Type 321 stainless steel to intergranular corrosion in boiling $CuSO_4$ solution. As the ratio of titanium to (carbon minus 0.03%) was raised from 5:1 to 15:1, the sensitization time increased from 1 to 40,000 hr, and the temperature for earliest sensitization fell from 1300 to 1000° F.

• Corrosion tests in 1% HCl and 60% H_2SO_4 showed that welds in five titanium alloys had the same corrosion resistance as base metal.

• The reaction of the coating with the molten globule at the end of a covered electrode during arc welding was studied by adding radioactive phosphorus to a lime-fluorspar covering and to a 6020 covering. In the first case the phosphorus content of the globule decreased as the drop grew in size, indicating absorption of phorphorus by the slag. In the second case the reverse occurred.

• A solution is given for the differential equation relating the aerodynamic resistance of a welding arc to bending by a transverse magnetic field. The solution relates welding current and field strength to the radius of the arc.

• A constricted arc torch with argon was used with filler wire to surface mild steel and to weld tubes to tube sheets. A rotating magnetic field was used to spread the arc and reduce depth of penetration.

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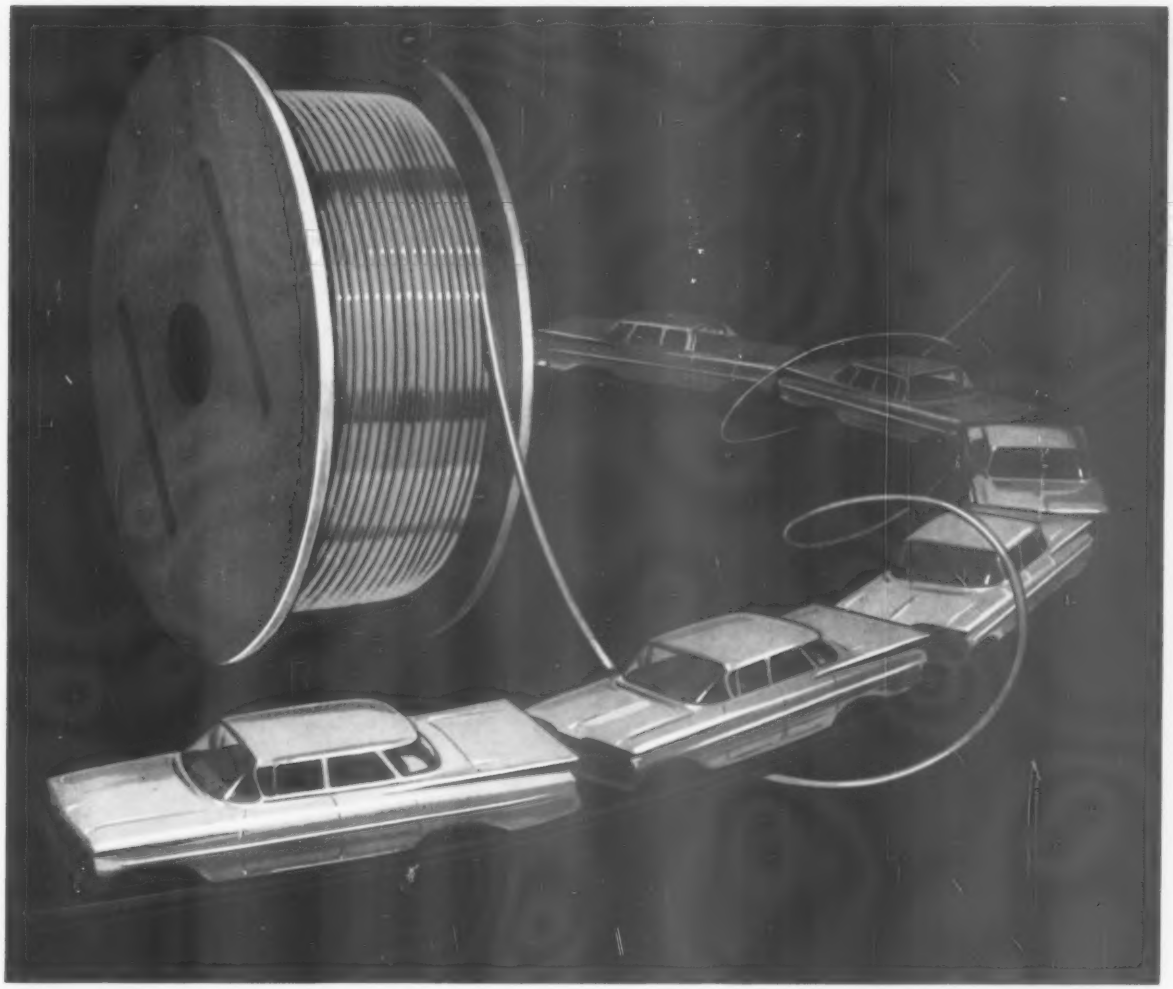

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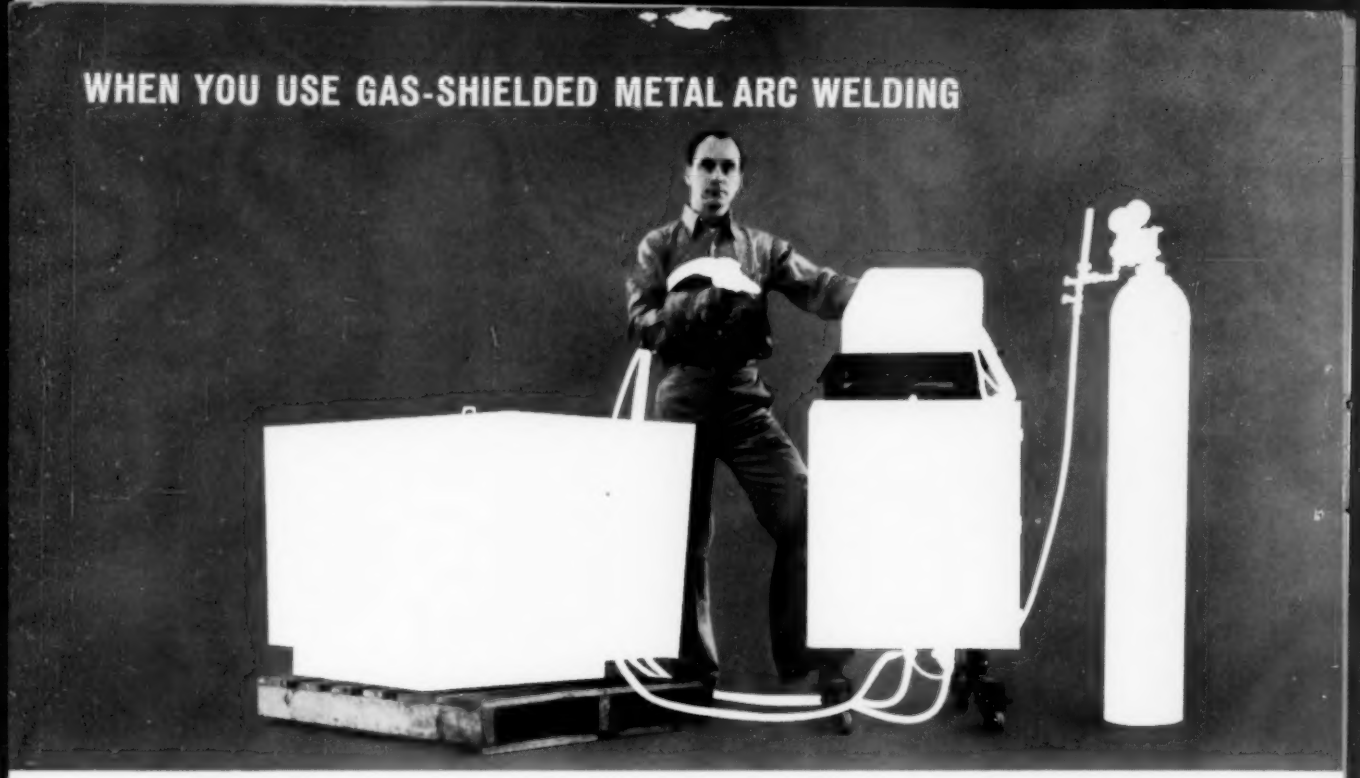

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